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DEPARTMENT OF THE INTERIOR
ALBERT B. FALL, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

PROFESSIONAL PAPER 123

A SUPERPOWER SYSTEM FOR THE REGION BETWEEN BOSTON AND WASHINGTON

BY

W. S. MURRAY AND OTHERS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1921

DEPARTMENT OF THE INTERIOR
Albert B. Fall, Secretary

UNITED STATES GEOLOGICAL SURVEY
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Professional Paper 123

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FOREWORD.

By George Otis Smith.

In December, 1918, President E. G. Buckland, of the New York, New Haven & Hartford Railroad Co., at the instance of Mr. W. S. Murray, consulting engineer, of New York City, urged upon Secretary of the Interior Lane a survey of the sources of energy in New England and on the Atlantic seaboard as far south as Washington. Secretary Lane's response was that general and local studies of the country's available power had been pushed with vigor by the Geological Survey as a war measure and that the continuation of this work was already planned under a special appropriation asked from Congress, but as the plans had not contemplated work on the scale suggested by Mr. Buckland the Secretary invited conference and advice, for he at once saw the advantage of making this intensive analysis and working out a plan to provide for the ever-growing energy requirements of this industrial region.

On January 27, 1919, the Secretary of the Interior sent to Congress a supplemental estimate of "an appropriation in the sum of $200,000 for a special investigation and report on the power supply for the Boston-Washington industrial region, to be made during the fiscal year 1920." Explanatory letters in which a constructive national power policy was urged were addressed to the chairmen of the committees on appropriations. "The country," said Secretary Lane, "is now passing through a period of transition, which, I firmly believe, will soon be followed by one of industrial activity and expansion. The enormous development of war industries had created an almost insatiable demand for power, a demand that was overreaching the available supply with such rapidity that, had hostilities continued, it is certain that we should now be facing an extreme power shortage. Happily such a crisis was averted by the signing of the armistice, and the ensuing curtailment in the demand for war materials has carried us past immediate danger of a power famine in the industrial districts of the Northeast."

The Director of the United States Geological Survey was heard on the proposal January 30 before the Appropriation Committee of the House. The proposal excited interest but lacked wide support, and the committee failed to report the item for further consideration by Congress.

During 1919 the subject of power conservation was fully discussed before engineering societies and trade and commercial bodies and in the technical and financial journals, so that the appropriation item was better received at the next session of Congress. Mr. Murray, who had accompanied Mr. Buckland in the earlier conference with the Secretary of the Interior, was foremost in winning both popular and professional support for the idea, and the strongest presentation of the subject to the House Committee on Appropriations was made by a committee appointed by the Engineering Council, of which Mr. Murray was chairman and L. P. Breckenridge, professor of mechanical engineering, Yale University; D. C. Jackson, professor of electrical engineering, Massachusetts Institute of Technology; and M. O. Leighton were the other members.

An appropriation of $125,000, carried in the sundry civil appropriation act for the fiscal year 1921, among the items under the United States Geological Survey, authorized the proposed investigation in the following language:

> For the survey of power production and distribution in the United States, including the study of methods for the further utilization of water power, and the special investigation of the possible economy of fuel, labor, and materials resulting from the use in the Boston-Washington industrial region of a comprehensive system for the generation and distribution of electricity to transportation lines and industries, and the preparation of reports thereon, $125,000. The Secretary of the Interior is authorized to receive any sums which may be contributed for this purpose. Such sums shall be deposited in the Treasury and credited to the appropriation herein made and be available for expenditure for the purposes thereof.

The work was promptly organized, and a strong engineering staff was selected by Mr. Murray, who had been appointed by the Secretary of the Interior as the logical man to head this engineering study. The engineers appointed to assist Mr. Murray have met every expectation, and great credit is due to them for their tireless enthusiasm for the work, inspired by both professional and public spirit, and to Mr. Murray for his wise choice of associates. Chief Hydraulic Engineer Grover, of the United States Geological Survey, and Chief Mechanical Engineer Hood, of the Bureau of Mines, became members of the engineering staff, so as to coordinate this special study with the current investigations of the Federal bureaus. This special short-period study was administered as a unit under the water-resources branch of the Geological Survey.

Secretary of the Interior Payne added to the driving force of this intensive study an advisory board consisting of men of vision and experience, representing our railroads, both steam and electric, and manufacturing, engineering, and chemical industries. These busy men held eight meetings during the year—a service that has added value to this report as now presented. The legal and financial aspects of the superpower project formed the subject of discussion at several of the meetings of the advisory board, but the formulation of conclusions on these aspects was deemed inopportune without further consideration, which it is proposed may be given by the board under authority of new appointments by Secretary of the Interior Fall.

The cooperation of all the industries affected by the proposed larger electrification was unstinted. Engineering aid was freely given, data were promptly furnished, and money was generously contributed as needed. No "dollar-a-year" men were engaged on this work, but under the specific authority of Congress $26,000 was contributed by 36 corporations and individuals representing utilities and industries in the zone.

The advisory board, under the leadership of Prof. Breckenridge, was kept fully informed of each step in the engineering study of the problem, and the active interest of many of the members led to constructive criticism, but no further responsibility for the conclusions here reported can be placed upon the advisory board. For the work done in the engineering staff a division of responsibility and credit is necessarily difficult, as here a group of workers has thoroughly coordinated its endeavors. In the appendixes to the report the responsibility of authorship has been indicated so far as possible, but the credit for the successful issue of the year's work must be given to the staff as a whole.

The investigation was begun on July 1, 1920, and the report was completed on June 30, 1921, as contemplated by Congress, a result in itself creditable to all connected with this special study.

June 30, 1921.

A SUPERPOWER SYSTEM FOR THE REGION BETWEEN BOSTON AND WASHINGTON.

By W. S. MURRAY and others.

SUMMARY REPORT.

By W. S. MURRAY.

INTRODUCTION.

On first presenting the subject considered in this report to the late Secretary of the Interior, the Hon. Franklin K. Lane, I used the word "superpower" to describe a system that would furnish power to the railroads and the industries within the territory between Boston and Washington that has now become more familiarly known as the superpower zone. (See Pl. I.) The system in turn has become known as the superpower system, and as the investigation has progressed it has taken the form of a proposed entity capable of incorporation as either one or more superpower companies.

My association with the power business during the last 15 years in the electric utility, railway, and manufacturing fields had so forcefully impressed upon me the unnecessary waste of money, labor, and material incident to the present form of power production by unassociated units that it seemed a constructive move in the interest of large national economy to present a plan for coordinated power production which would prevent this waste.

In reading this report two things should be kept in mind—first, that the economy in power production and distribution thus far attained has been due largely to the electric public utilities; second, that the failure to attain the highest possible economy has been due largely to restrictive policies that have inhibited the expansion of electric public utilities.

If this report accomplishes nothing more than to show the saving in labor, material, and money that could be effected by the installation of a power system adequate to serve both the railroads and the industries in the superpower zone, then, by the token of this saving, I plead in the name of national economy for a broad policy in legislation, regulation, financing, and management that may not only remove the existing inhibition but may give positive encouragement to the expansion of electric utilities, especially within this zone, so that adequate, reliable, and cheap power may become available to permit the normal expansion in our industries, together with economical expansion in the capacity of our railroads to handle the increased tonnage incident thereto.

The physical details of the plan proposed are given under the heading "The superpower system" (pp. 13–15); but, in order that the true objective may not be lost and that the functioning of the whole, with its total result, may be comprehended, it should be remembered that the superpower system is nothing more than a superutility. All its parts will be fashioned similarly, like the parts, for example, of the New England Power Co., with its 12 power stations and its 750 miles of transmission lines; but owing to the greater capacities and distances involved in the superpower system, its generating units and transmission lines will be larger and more efficient than those now in use. It will make no difference whether the system is a single great superutility or several utilities built up separately and functioning in close relation to one another. In applying the principles to be set forth in this report the superpower system should be visualized as one great power project serving the superpower zone.

SUMMARY OF CONCLUSIONS.

The market for superpower energy will be furnished by the electric utilities, the industries, and the railroads. The estimated requirement for energy supplied through the electric utilities for municipal, private, industrial, and railroad purposes in 1930 is 31,000,000,000 kilowatt-hours. This energy could be supplied by a coordinated power system such as is described in this report at an annual cost of $239,000,000 less than by an uncoordinated system such as is now in use. This amount represents the net saving after the necessary fixed charges on total capital expenditure have been deducted. The cost of uncoordinated power production in 1930 is computed from the cost of the present system in 1919. The total investment in generating and transmission facilities for the superpower system will be $1,109,564,000, of which $416,346,000 will represent the value of existing facilities to be incorporated into the system.

A study of the 96,000 manufacturing establishments operating within the superpower zone shows that by 1930, through the maximum economical use of purchased electric energy, they can save $190,000,000 annually above the fixed annual charges against a capital investment of $185,000,000 to provide the motor equipment necessary to receive and use this power.

The combined capital investment necessary for the electric utilities and the industries as of 1930 therefore amounts to $1,294,564,000, and this total investment will yield annually above the fixed charges the sum of $429,000,000, or 33 per cent on the investment.

Within the superpower zone there are 36,000 miles of railroad measured as single track—that is, including each track of main lines, yards, and sidings. Of this total about 19,000 miles can be profitably electrified, so as to yield by 1930 an annual saving of $81,000,000 as compared with the cost of operation by steam. The capital expenditure necessary to electrify the 19,000 miles would be $570,000,000, and the average return upon the investment would therefore be 14.2 per cent.

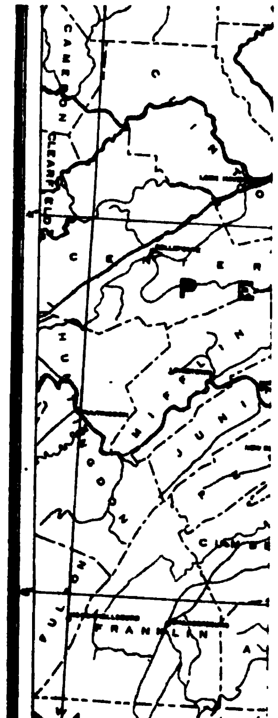
As defined in another section of the report, the superpower system begins at the generating stations connected to its lines and ends at the busses of existing electric utilities. Therefore, the cost of power discussed in this report means cost at the busses of the electric utilities and must not be confused with the cost to the ultimate consumer, which is necessarily much greater, owing to the added cost incident to secondary distribution systems.

Studies of the operations of each load center have shown that a large quantity of coal could have been saved had superpower facilities been available in 1919. On comparing the coal rates of power production in 1919 with those of the superpower system and applying the difference to the load that will exist in 1930 we find that the coal saved annually under the superpower system may be estimated as follows:

	Short tons.
Electric utilities	19,149,000
Heavy-traction railroads	10,210,000
Manufacturing industries	20,625,000
	49,984,000

The order in which the superpower steam-electric and hydroelectric power plants and transmission systems should be constructed must depend (1) on the present industrial demand for energy that can not be satisfied because of the difficulties of the local electric utilities in financing extensions; and (2) on the future demand for energy that will result from the more economical generation of power under the superpower system.

Many of the economies incident to superpower operation will be effected through the interconnection of existing plants and systems, and these economies should be increased as new power plants and interconnections are added. Certain steam plants that are under consideration and others that are under construction will be when completed as efficient as the proposed base-load steam-electric plants of the superpower system. Notable among these plants are the Hell Gate station now being constructed by the United Electric Light & Power Co. of New York City and the Delaware station of the Philadelphia Electric Co. However, by keeping in mind the two conditions, already stated, that should govern the order of construction, it is believed that the quickest return will be obtained by following in chronologic sequence the order of procedure outlined on page 13.


CAMERON
CLEARFIELD
PE
MIFFLIN
JUNI
FRANKLIN
WASH
M
BERKELEY
WEST
VIRGINIA
JEFFERSON
CLARKE
LOUDOU
MONT
VIRGINIA
FAUQUIER
PRINCE WILLIAM
FAIR

1. The construction of a steam-electric plant near Pittston, Pa., to supply a part of its energy to the Anthracite division of the superpower zone and the remainder to the Metropolitan division, particularly New Jersey.

2. The construction of a steam-electric plant near Sunbury, Pa., to supply a part of its energy to the Anthracite division, a part to the Reading load center, and the remainder to Philadelphia.

3. The construction of hydroelectric plants on Delaware and Susquehanna rivers to supplement the steam plants indicated in paragraphs 1 and 2.

4. The progressive development of the Hudson River projects to meet the growth of energy requirement at the Schenectady, Utica, Poughkeepsie, and Pittsfield load centers.

5. The construction of a steam-electric plant near Boston to supply the Boston, Lowell, and Newburyport load centers.

6. The construction of a steam-electric plant near New Haven to supply the New Haven, Bridgeport, Waterbury, and Norwich load centers.

7. The partial construction of the first hydroelectric plant in the development of Potomac River as soon as the power demands of the Baltimore and Washington load centers require additional plant capacity.

Plant capacities are not stated above, as they can not be finally determined except by further and more detailed study of local conditions combined with regional demands. The load growth at all the centers, however, will make it imperative to provide new plant capacity at an early date, so that the construction of additional plants, as detailed in Appendix E, must be started promptly after the plants that will yield the greatest return have been built.

THE SUPERPOWER SYSTEM.

The territory in which the superpower survey has been made—the "superpower zone"—may be described as lying between the thirty-ninth and forty-fourth parallels of latitude and extending from the coast approximately 150 miles inland, embracing parts of the States of Maine, New Hampshire, Vermont, New York, Pennsylvania, Delaware, and Maryland and all of the States of Massachusetts, Rhode Island, Connecticut and New Jersey. (See Pl. I.) Within this zone is concentrated one-fourth of the population of the United States, and within it are operated, most of them independently, 315 electric utilities, 18 railroads, and 96,000 industrial plants. The superpower zone is the finishing shop of American industry.

Unlike the Pacific coast region, where water power abounds and industry is relatively small, the superpower zone has relatively small hydroelectric resources and maximum industrial-power requirements. When the increases during the last 10 years are projected to 1930, even at a lower rate, the total energy requirement of the zone in that year is found to be 31,000,000,000 kilowatt-hours, of which about 21 per cent can be supplied from water power.

Fortunately some of the best coal deposits in the country lie near this great industrial territory, and a prime economic purpose should be so to conjoin the hydroelectric supply of power to the steam-electric supply as to produce a maximum of energy for a minimum investment of capital and a minimum operating expense, and at the same time to conserve the rapidly disappearing cheap fuels of the Appalachian coal fields.

The superpower system here recommended comprehends a plan of power production that includes the generation of electricity by steam at tidewater and on inland waters where a sufficient quantity of condensing water can be obtained, and also the utilization of all hydroelectric power that may be economically obtainable from rivers within the zone or within transmission distance of it. The electric power so generated will be coordinated through a system of interconnected transmission lines, the potentials of which will be on the order of 220,000 and 110,000 volts. (For the assignment of these voltages see Appendix E.)

Plates II and III show how the superpower system should appear in 1925 and 1930. They give the locations of the new steam-electric plants, the hydroelectric plants, and the load centers for each year and show the interconnecting network of transmission systems required. Had superpower been available in 1919 the number of load centers to which its power could have been supplied economically would have been 20, and this number as the maps show, will increase to 34 in 1930.

Under the present independent operation of the electric utilities and the manufacturing industries in the superpower zone the existing power plants are numerous and small. The average capacity of the 558 electric-utility plants now in operation in the zone is 7,900 kilowatts, and that of the steam-electric plants 10,000 kilowatts, while the hydroelectric plants average only 2,800 kilowatts. Out of 96,000 industrial establishments in the superpower zone 76,000 use power, and each of these isolated plants averages about 350 horsepower. Under the superpower system, by contrast, the number of power stations required to supply the entire zone in 1930 will be only 273, of which 218 will belong to the existing electric utilities. The capacity of the base-load steam plants will range from 60,000 to 300,000 kilowatts. In none of these plants will there be installed a turbo generator having a capacity of less than 30,000 kilowatts.

The new power stations and load centers will be so located with reference to the existing electric-utility plants that are to be incorporated in the system as to insure the maximum aggregate economy in power generation and transmission. A prime object to be attained in the superpower plan is the maximum economic utilization of existing generation and transmission equipment. In the early stages, while the superpower system is taking form, existing electric-utility capacity will predominate. Indeed, in 1930, as much as 31 per cent of the total superpower capacity will be contained in plants belonging to the present electric-utility companies.

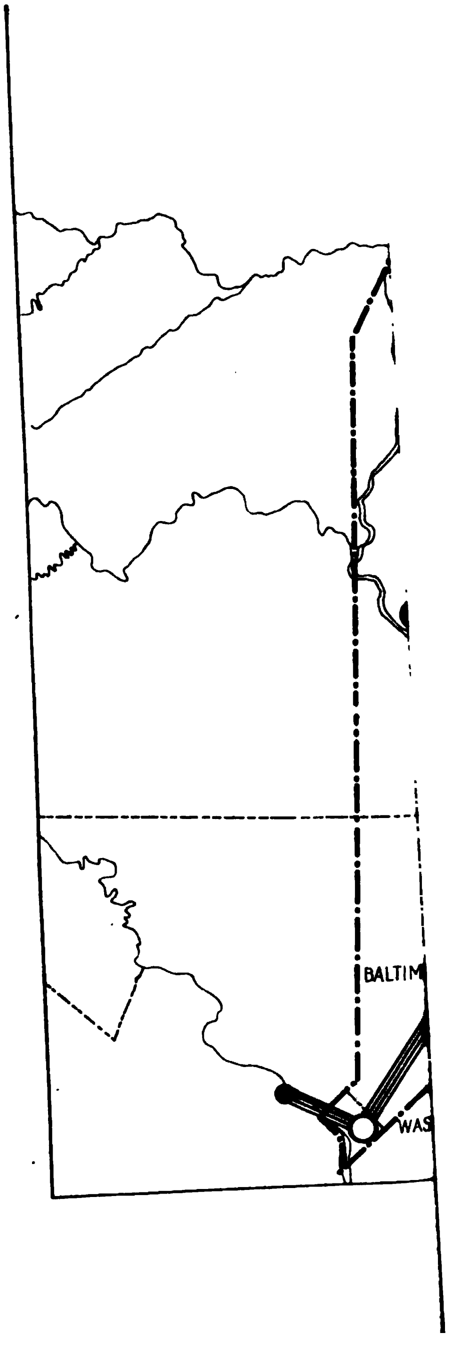
The superpower system would and should fail to achieve its purpose if it should seek to supplant or even to compete with the existing electric utilities. Its object is exactly the reverse. In view of the great economies already effected by the electric public utilities, the creation of the superpower system can be urged only as it shall come into being to coordinate and supplement these utilities and carry to a higher degree the service and the economies incident to their present operation.

It should not be difficult to see, therefore, that the superpower system will provide for a series of load centers, at which power may be made available at lower cost than can be attained under the present unassociated systems of power production and distribution. At these load centers, located where economy may dictate, power so made available will be coordinated with power generated at existing electric-utility plants and distributed by transmission or distribution systems to the consumers, as it is to-day.

Under the heading "Summary of conclusions" it was stated that in the operation of electric utilities the superpower system, in comparison with independent operation, would save $239,000,000 in 1930. The question might be asked, Could not the same result be attained by the electric utilities themselves in the course of their normal expansion? The coordinated plan of power production by the superpower system represents the highest possible commercial efficiency and must therefore yield the maximum economies. I believe that no possible expansion of the present uncoordinated electric public utilities can reach the economic results promised by the superpower system, for the physical structure of the superpower system, as outlined in the appendixes to this report, employs minimum capital and minimum labor to produce a maximum of electric energy.

In the discussion of the superpower system there has been some tendency to look upon it more as a company than as a principle, but the foregoing statements should make it clear that superpower is merely a name for the principles that should govern the expansion of the existing electric utilities. A better term than superpower would have been superutility.

The electric utilities, the railroads, and the industries within the superpower zone have freely given their data to permit a determination of the amount and location of load and demand and have supplemented them with data showing the cost of producing their power in 1919. The superpower system will be a regional system supplying power through the electric utilities, at the highest economy, to the two agencies that are most vital to American existence—industry and transportation. The highest economy in investment and operation will be gained by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maintaining the size of the electric generating units at a maximum and thus reducing capital and operating cost to a minimum. The highest economy resulting from diversity economy will be gained through a wisely ordered interconnecting system of lines of transmission and distribution—a system which also offers the highest economy in the development of water power, for it makes possible the use of a maximum number of cubic feet of water per square mile of drainage area, thus reducing to a minimum the amount of power generated by steam.

In determining the amount and cost of the power produced within the superpower zone it was obviously necessary to select the latest year for which full construction and operating information could be obtained—the year 1919. On account of the extremely high cost of material in that year, however, this selection has introduced high fixed charges; but this is offset by the saving in high-priced coal and the consequent reduction in operating expenses resulting from the higher efficiency of the superpower system as compared with the present independently operated electric utilities.

As efficiencies have increased with the enlargement of the plants operated, the cost of producing power has been lowered. The best reflection of this decrease in cost is seen in the electric utilities themselves. Much of it has been the result of interconnection, which has permitted the use of larger machinery and a better utilization of water power. In the isolated plants and on the railroads, however, although the cost of power has been lowered, the decrease has been far less, because in both of these the power equipment is small and its operation is affected by conditions that prevent much gain in efficiency.

It may be argued that it would be unfair to extend the costs of independent operation for 1919 to 1930 and at that year strike a difference between them and those of the superpower system. This argument can not be gainsaid, but if the figures representing the cost in 1919 of unassociated power production are not lowered by 1930 then the full savings previously indicated as possible by the superpower system can be claimed. Unquestionably the figures for 1919 will be lowered by the further consolidation of existing utilities, but unless the electric utilities act in complete cooperation and themselves adopt a plan of coordinated expansion by which the load centers of the zone can be supplied with power at minimum cost then the economies they can independently effect will never reach the maximum attainable under the superpower system, which involves the complete coordination of the existing power stations of the electric utilities and the new stations to be constructed.

DEFINITIONS.

A few of the terms used in this report are defined below:

Assigned locomotives.—Locomotives actually engaged in runs between terminals or in switching operations.

Base-load plant.—A generating plant designed to carry that part of the load which is practically continuous.

Capacity factor.—The average load on a plant expressed as a percentage of the effective capacity of the plant.

Class 1 railroads.—Railroads having an annual operating revenue of $1,000,000 or more.

Cost of power delivered.—The sum of the cost of production and transmission and the general expense.

Diversity economy.—The saving made by interconnecting generating stations whose peak loads are reached at different times and so distributing the load among stations of different unit operating costs as to deliver power at minimum cost.

Diversity factor.—The ratio of the sum of the maximum power demands of the subdivisions of any system or part of a system to the maximum demand of the whole system or of the part of the system under consideration, measured at the point of supply. (Standards of the American Institute of Electrical Engineers, section 3464.)

Effective capacity.—The rated capacity of a plant as limited by boilers, prime movers, or generators.

Fixed charges.—The cost of money, depreciation, obsolescence, taxes, and insurance.

General expenses.—The administrative, legal, and fixed expenses and expense of office supplies.

Load factor (hour yearly).—The ratio of the average power to the peak power expressed as a percentage of the peak power.

Operating cost.—The cost of fuel, operating labor, maintenance, (including depreciation and obsolescence) and supplies.

Peak-load plant.—A generating plant designed to carry the peak loads.

Production cost.—The sum of the operating cost and fixed charges for a power plant.

Reproduction cost.—The cost in midyear of 1919 of an up-to-date plant of the same capacity.

Total ton-miles.—The weight of the train in tons, including the locomotive and tender, multiplied by the distance run in miles.

Trailing ton-miles.—The total weight of the train in tons, exclusive of the locomotive and tender, multiplied by the distance run in miles.

Transmission system cost.—The sum of the operating cost and fixed charges for a transmission system, including substations.

SUMMARY OF APPENDIXES.

The problem set for the engineering staff, briefly stated, was that of determining the total amount and the location of the power load that would be required for municipal, private, industrial, and railroad purposes at a date sufficiently in advance to permit the construction of a system of the highest economy to supply it. The date chosen was 1930, and the allocation of the load and the power-generating facilities for the six geographic divisions of the superpower zone is shown in Appendix E.

In the earlier stages of the investigation, therefore, the entire attention of the engineering staff was concentrated upon the work of determining the amount and the location of the load. This work was done through the cooperation of the electric utilities, the railroads, and the industries within the zone. The engineering staff then undertook to determine the amount and the location of generating and transmission capacity to supply the demand thus ascertained.

The appendixes, which are here only briefly summarized, are largely, if not entirely, the work of their authors, to whom reference is made under "Organization," in Appendix A. I believe I can fairly say that in the endeavor to solve the problem set for us the engineering staff followed a route in which my principal engineering associates, Messrs. Butler, Flood, Hutchinson, and Imlay, were in full accord with me. To them and to their assistants may be ascribed the full credit for the collection of the information required for the report and a very large share of the credit for working it up. For the details that served as the groundwork for the conclusions reached I would suggest a careful study of the appendixes.

Appendix B. Electric utilities in independent operation in the superpower zone in 1919.

In the New York, Baltimore, and Washington load centers the predominating frequency is 25 cycles; in the remainder of the zone it is 60 cycles.

The electric-utility load will grow from approximately 10,000,000,000 kilowatt hours in 1919 to 26,000,000,000 kilowatt hours in 1930. The figure for 1930 has been predicated upon an annual rate of growth of 9 per cent, a safe figure, for the annual rate of growth during the last 10 years has been 11 per cent.

Figure 1 shows the distribution of electric-utility load between Boston and Washington by load centers for 1919 and indicates the tremendous concentration of power in the vicinity of New York City. The data given by the electric utilities concerning load growth are shown graphically in figure 21, which indicates the decentralization of power that will have taken place by 1930.

It is apparent that the locations for future electric-power plants must lie outside the densely populated districts. The high-voltage circuits of the superpower system in general will form ring busses around the larger cities of the zone, on the outskirts of which will be located substations with transformers having their primaries connected to the superpower circuits and their secondaries connected to the existing distribution lines of the electric utilities.

The peak loads for the Anthracite and Mohawk-Hudson divisions occur in the morning. The peaks for the other divisions occur in the afternoon. The annual peak for the zone as a whole occurs about 5 in the afternoon, usually in December.

Out of 558 electric-utility plants in the superpower zone there are but 36 whose capacity equals or exceeds the average capacity of the plants for the superpower system in 1930. Out of the 1,074 generating units of 500 kilowatts or more operating within the zone in 1919, only about 20 had a capacity greater than 30,000 kilowatts.

It is of interest to note that a plant delivering power with a load factor of 40 per cent turns out 76 per cent of its energy (kilowatt-hours) before its capacity (kilowatts) has been taxed 40 per cent, the remaining 60 per cent of its capacity being required for the remaining 24 per cent of energy, thus showing the small amount of energy involved in peak operation. This statement brings out the very important point that the superpower system employs the generating capacity of the existing electric utilities for application to peak loads, the new and larger superpower stations contributing their low-cost energy for base load.

The relative cost of power production by large and small units is shown. A comparison of the production cost for plants greater than 100,000 kilowatts with that of those less than 1,000 kilowatts shows a ratio of 3 to 1 for cost of fuel and 4 to 1 for cost of maintenance and supplies in favor of the larger plants. With these marked economies in mind, it is clear that base load should be supplied from superpower plants employing units of not less than 30,000 kilowatts each.

Table 3 brings out the performance of 400 steam-electric plants and 158 hydroelectric plants operating within the superpower zone in 1919. The fuel rate for the average steam-power plant is 2.73 pounds per kilowatt-hour, with a heat requirement of 35,800 British thermal units per kilowatt-hour. These figures contrast strikingly with the fuel rate of 1.41 pounds per kilowatt-hour and the heat requirement of 18,300 British thermal units per kilowatt-hour that can be obtained from the base-load steam-electric plants of the superpower system operating at the same annual capacity factor.

Under independent operation in 1919 the generating capacity required was 46 per cent greater than the annual peak load, and the resulting annual capacity factor was 26 per cent; under the superpower system in 1930, through joint reserve, the generating capacity required will be only 9 per cent greater than the annual peak, and the annual capacity factor will be 45 per cent.

The reproduction cost for steam and hydroelectric plants under independent operation as of 1919 is $156 per kilowatt of capacity; the corresponding cost under superpower operation is $125 per kilowatt.

The average unit production cost for the electric utilities in 1919 was 1.93 cents per kilowatt-hour; the cost of the electric power produced by steam was 2.12 cents, and that of the hydroelectric power was 0.94 cent. In the steam-electric base-load plants for the superpower system the production cost, based upon the same capacity factor that is applied to electric independent operation, will be 0.99 cent per kilowatt hour, as compared with 2.12 cents.

Appendix C. Proposed electrification of heavy-traction railroads in the superpower zone.

Density of traffic is the controlling factor in railroad electrification. Within the superpower zone there is a large railroad mileage upon which the traffic is sufficiently dense to require careful consideration of the savings to be effected by electrification—in fuel, in maintenance of equipment, and through economies incident to the reduction in train-miles.

The zone contains some 36,000 miles of main line, yards, and sidings, of which 19,000 miles could be profitably electrified. The total capital expenditure necessary to electrify this mileage is $570,000,000, and the result of the analysis promises an annual saving of $81,000,000, or 14.2 per cent on the investment.

The response by the railroads to requests for data relating to their operations in 1919 has been so generous and the compilation of these data in this appendix, with the conclusions deduced from them, is so complete that instead of attempting to summarize the appendix I will only refer to the more general aspects of the problem.

In the earlier days of railroad electrification, as, for example, on the New York Central, the New Haven, and the Pennsylvania, we were all groping and feeling our way. That was 20 years ago, and in this age of rapid progress 20 years is a long time in which to make up our minds regarding the fundamental principles of electrification. Even the dyed-in-the-wool steam-locomotive man has become interested in the electric locomotive, because he has found that the steam locomotive can not perform its work satisfactorily in the environment that belongs to the electric locomotive. The reverse is also true—there are railroad tracks on which electric locomotives have no place. To find where electric train propulsion should be used does not, however, completely solve the problem. Money must be obtained to put electric locomotives where they belong.

When the electrified portions of the New York Central, the New Haven, and the Pennsylvania were first operated the railroad companies paid out their own dollars for their motive-power equipment and for the power stations to run it. The whole expenditure was therefore borne by the railroads. About that time Mr. Samuel Insull, with far-seeing perspective, declared that the power required for electrified railroads should come from the large electric-utility plants. I am glad to admit that I was wrong when with others I disagreed with him. I am more glad, however, to say that I stayed wrong only long enough to make up my mind to be a party to a contract for 40,000,000 kilowatt-hours per annum from the United Electric Light & Power Co. to supply the west end of the electrified stretch of the New Haven road. Since that date it has been my belief that the production of electric energy should be confined to those in the power business and that the railroads should purchase electric energy and confine themselves to the transportation business. The railroads will thus be assured of adequate, reliable, and cheaper power and will be relieved of the cost of building their own power stations.

A further step of fundamental importance that would lighten still more the burden of investment cost, which at this time the railroads are so peculiarly unfitted to carry, would be to standardize as far as possible the motive-power equipment required for the three classes of railroad service—passenger, freight, and switching. Such standardization would simplify electrification and therefore reduce the cost of maintaining equipment, as well as lessen the investment cost. Motive-power equipment so standardized as to be operative on 19,000 miles of track would offer a foundation for an equipment trust bond that would be most attractive to bankers and would relieve the railroads of a heavy capital requirement. In short, the railroads, not being called upon to build motive-power equipment or power stations, would have to pay only the electrification cost incident to their contact and distribution lines, and the charge against their capital account would be only 20 to 25 per cent of the amount required 20 years ago, when they were paying 100 per cent of the cost of electrification.

I hold no brief in this report with regard to systems. It has been well said that either the direct-current or the alternating-current system is better than steam. After these 20 years of heavy-railroad electrification one can not close his eyes to the advantages or disadvantages of either system. Though I was instrumental in selecting and installing the single-phase (alternating current) system on the New York, New Haven & Hartford Railroad, I am conscious of two elements that may militate against this system—(1) the low power factor, which calls for unproductive capacity in power-plant and transmission equipment, and (2) the undeniable fact that this system induces serious electromagnetic effects upon adjacent telegraph and telephone facilities. In the high-voltage direct-current system electromagnetic induction is practically eliminated, but that system has not yet offered a practical multiple-control unit equipment such as is necessary to suburban operation. On the other hand, the multiple-unit equipment of the high-voltage single-phase system has given the highest satisfaction on the railroads that use it. But these are mere details. The best high-voltage direct-current multiple-unit equipment must be worked out if the railroads in this zone are to be so operated. If power is obtained from substations of electric-utility companies the investment cost will be practically the same for either of the two systems.

This explanation should make it clear that neither system is here favored as against the other, notwithstanding the fact that in Appendix C the 3,000-volt direct-current system has been employed in making the estimates of construction cost. This has been done only in order that a complete system of construction figures could be worked out, from the superpower stations to the driving wheels of the motive power.

Although the zone is large enough to permit the use of both systems, I would emphasize the recommendation that the great electric manufacturing companies of this country draw together rather than apart and that they unite in a common specification for electric motive power to replace steam, for the final result would be tremendously improved by this action.

In addition to the argument that the railroad companies should buy power from the electric utilities because the utilities are in the business of producing power, there is the very excellent argument that the railroad load will not only swell the output of the utilities and therefore permit the installation of larger and more economical generating units but will produce the inherently high load factor common to railroad operation and thus tend to promote the maximum use of the generating capacity installed.

In contrast with the indicated return of 33 per cent to the electric utilities and the industries through the operation of the superpower system the average return to the railroads on the investment necessary to electrify 19,000 miles will be only 14.2 per cent. Of course the percentage of return will vary from division to division, and figure 15 (p. 77) shows that this variation will be from 11 to 19 per cent. Naturally, therefore, the selection of railroad properties to be electrified, aside from requirements for pure increase in capacity, will be governed by the percentage of return to be expected. The greater savings attainable by the utilities and the industries should not overshadow the urgent requirement of railroad electrification. As measured to-day a money return of 14.2 per cent is good, and I think it can be fairly said that we must now begin to live into the new form of train propulsion that is offered by electricity, for thus will be created a means of railroad expansion to support the coming American industrial expansion, which our resources and the world requirements can not possibly fail to induce within the near future. No one can deny that the system in which we must live should carry with it prime principles of economy, which will include these features of commercial efficiency. Any saving in the consumption of coal by the railroads means the transfer of cars from wasteful to productive transportation.

The normal amount demanded annually for extensions and betterments for the railroads within the superpower zone is approximately $150,000,000, an amount which even in the face of present construction prices would suffice in three or four years to cover the cost of electrifying all the mileage mentioned. Should we continue to tinker with an old and inefficient machine when it is impossible to escape the installation of the modern and efficient one?

The higher price of coal and labor of the future compared with pre-war prices, which has dislocated the economic balance between railroad grades and the tractive power of locomotives; the lack of sufficient motive power that has been plainly demonstrated at critical periods in recent years; the steady increase in the tractive capacity of individual locomotives noted during the last 20 years; and the present hauling of trains weighing two to three times as much as those of the recent past are plain indications that in the near future large sums of money must be expended for motive power.

The well-known characteristics of electric locomotives, whose capacity and speed are not limited by rail and bridge strength and tunnel clearance, make electrification the true system into which we must promptly grow or pay the price for delay. This aspect is one entirely apart from that of the returns to be expected on the proposed capital investment shown in this report.

Appendix D. Industry in the superpower zone.

The maximum economical use of purchased power in the superpower zone in 1919 would have produced a saving in coal amounting to 13,502,100 tons. To determine this saving it was necessary to acertain the coal-burning rates of the industries that developed their own power as against the rates that would have been required to supply them power from central stations.

Out of 96,000 individual establishments in the zone 76,000 used power. The industries analyzed included manufacturing establishments, laundries, mines and quarries, and Government manufacturing institutions. In Table 48 the industries are listed under 17 main groups, which are so subdivided as to form 53 classes.

The fundamental information required for the determination of the mechanical power-supply equipment and fuel used by all the industries necessarily had to be procured from the Bureau of the Census, if for no other reason because time would not have permitted its independent compilation. This information is presented in the tables of the appendix variously—by character of power supply, by industrial subgroups, by county, and by size of plant. The presentation of the data in this form appears not only to be essential to this analysis but should be of great interest and value to all engineers who are interested in industrial power and heat.

The analysis showed that in 1919 the equivalent of 9,311,440,000 kilowatt-hours was developed by prime movers operated by the industries themselves and that 3,338,800,000 kilowatt-hours was purchased. It further shows that it would have been economical to shut down 4,008,200 horsepower of prime movers and purchase energy to the amount of 5,623,800,000 kilowatt-hours, which would have made a total of 8,962,600,000 kilowatt-hours purchased in 1919. The saving in coal thus effected would have been 13,502,100 tons—71 per cent of the coal used by the industries for producing power, or 25 per cent of all the coal used by the industries. In making the industrial power analysis care has been taken not to invade the field of what might be termed by-product power—that is, power produced by the industries from coal that would have been burned anyway for heat and in industrial processes. The saving determined is that made on coal burned for power and chargeable to the supply of power. It has been difficult to separate one class of coal burning from the other, yet after consultation with many authorities a separation has been made..

In general it has been found that industrial establishments which require 500 horsepower or less can economically purchase energy. Only those that need more than 500 horsepower and that have special requirements for heat can generate their own power economically, and even these should have central-station connections to take up irregularities of load. The efficiency of power production by isolated industrial plants is precluded from any considerable improvement by their necessarily small average capacity.

A careful study of the power requirement for industrial establishments in the superpower zone has been made and has shown that by 1930 an annual saving of $190,000,000 can be made to the industries themselves above the fixed charges against an investment of $185,000,000 for the motor equipment necessary to utilize the power.

Such a result will not of course be effected by any mysterious magical act of a superpower system. Indeed, many of the electric utilities have already been in a position to offer large savings to the industrial plants within reach of their distribution circuits.

In this study of the economical generation and distribution of power throughout the superpower zone full allowance has been made for the capital required to place regional plants in action, with their generating and transmission equipment connected with the distribution systems of the existing electric utilities, so as to reach every industrial worker in the zone. It is therefore hoped that this presentation of the saving that can be made may prove worthy of consideration by the executive officials of the industrial establishments in the zone.

Appendix E. Performance and cost of the superpower system.

Appendix E summarizes the report. It is built up of the appendixes that precede and follow it. It gives the investment cost and the cost of power delivered to the load centers for 1919, 1925, and 1930.

The cost of power at the busses of the electric utilities includes a return of 10 per cent on the money invested in the generating and transmission system. It is thought that during this present period of high interest a yield of not less than 10 per cent would be required to attract the necessary capital to this form of investment.

Figure 1 shows the distribution of load in the superpower zone in 1919. A comparison of this diagram with figures 20 and 21 brings out the degree of decentralization that is possible through the agency of a superpower system. The 20 load centers of 1919 are increased to 34 by 1930, and the superpower transmission system can not economically be tapped for a load of less than 20,000 kilowatts.

The frequency selected for the superpower system is 60 cycles. At the New York, Baltimore, and Washington load centers the principal frequency is 25 cycles, but generator sales in the ratio of 9 to 6½ in favor of 60-cycle apparatus during the last 5 years and generated output in the ratio of 4.75 to 2.2 during the last 10 years unquestionably establish the trend and determine the choice for the superpower system.

The regional diversity existing in the superpower zone is assumed to be of more theoretical than practical importance, except the diversity existing between the Anthracite, Metropolitan, and Southern divisions, which will become very marked with the growth of the Anthracite division load by 1925 and 1930.

Capacity to provide for load growth has been determined largely from the trend of the load factor. (See pp. 154–156.) The load factor for the electric utilities within the zone increased from 34 per cent in 1910 to 39 per cent in 1919. In some of the geographic divisions, such as the Metropolitan, the increase in load factor has been very slight; in others it has been large—for example, in the Southern division the load factor has increased from 33 to 43 per cent, largely owing to additions of industrial load.

In 1919 only 15 per cent of the total output of the electric utilities was hydroelectric power. By 1930 this proportion will have been increased to 21 per cent. In 1925 50 per cent of the total generating capacity for superpower operation will be contained in plants owned by the present electric utilities, and they will produce about 26 per cent of the energy. By 1930 the corresponding percentage of generating capacity will have dropped to 39 per cent, and these plants will furnish only 18 per cent of the total output. They will be used principally to carry peak load.

In 1919 the average size of the electric-utility plants within the zone was 7,900 kilowatts; by 1930 this size will be increased to 29,900 kilowatts. An even more marked contrast is that between the average size of new steam-electric plants to be installed, which is 218,000 kilowatts, and the average size of the steam-electric utility plants existing in 1919, which is 10,000 kilowatts.

Of far-reaching importance, in my opinion, will be the maximum use of diversity economy made possible by the interconnecting circuits of the superpower system. By diversity economy I mean the ability to select capacity that will produce power at minimum cost.

The unit investment cost in new power plants for the superpower system is $118.25 per kilowatt of effective capacity; that for all plants is $125 per kilowatt. The unit reproduction cost of the electric utilities in 1919 was $156 per kilowatt of effective capacity. This reduction in cost for the superpower system is due to the greatly increased size of the plants. The contrast is even more striking in the unit investment cost per kilowatt of demand, which is $196 per kilowatt for independent operation and only $136 per kilowatt for the superpower system.

In 1930 the transmission system of the superpower system will represent 9.3 per cent of the total investment cost.

The new money required for the superpower system up to 1925 is $453,143,000 and up to 1930 $693,218,000, thus making it necessary to raise $90,600,000 annually for the first five years and $48,000,000 annually for the following five years. The early installation of a transmission network calls for the higher rate for the first five years. This rate, however, is justified by the annual saving resulting from interconnection.

If the demand of 1930 were provided for by the independent systems as constructed to-day the total sum required would be $856,000,000, or $85,600,000 a year. Accordingly the construction of the superpower system will involve a saving in investment cost of $163,000,000 during the next 10 years; in other words, the increase of capacity to meet growing demands can be financed by the superpower plan for $16,300,000 annually less than by the normal expansion of the existing electric utilities. On page 169 a full comparison is made between independent operation and superpower operation for the years 1919, 1925, and 1930. The net annual saving by 1930 above fixed charges and capital is approximately $239,000,000.

Of great interest is the economic relation established between the joint use of steam and water power. It is shown that steam and water power can be so combined as to yield annually

$69,550,000 on an increased investment of only $44,838,000. Here is exemplified one of the prime advantages of superpower production, costs being reduced by means of the interconnecting system which permits the highest economy in steam-produced power together with the maximum use of water power.

The load growth in the Eastern New England, Western New England, and Mohawk-Hudson divisions should be sufficient to absorb the total available output of the St. Lawrence project by 1932; and the growth in the Metropolitan division should be sufficient to absorb 300,000 kilowatts at a load factor of 80 per cent from Niagara in the same year. Power could doubtless be purchased from these hydroelectric plants at not over $20 per horsepower-year delivered at their bus bars, and accordingly this figure is used in determining the effect of this arrangement on the cost of power to the divisions of the superpower zone that would be so supplied.

The total annual cost for power delivered in 1932 to the load centers of the Eastern New England, Western New England, and Mohawk-Hudson divisions, if St. Lawrence power is used, will be $130,273,000; if the excess energy required in 1932 over that of 1930 were furnished by new steam-electric plants the cost would be about $141,601,000. The development of St. Lawrence River would therefore save $11,328,000 a year to these geographic divisions; moreover, the total investment required to utilize purchased St. Lawrence power would be $24,826,000 less than that required to construct new steam-electric plants to supply this excess energy. In the three divisions mentioned, which lie farthest from the coal fields, the cost of power generated by steam plants is inherently high, and therefore the St. Lawrence development will be of very great benefit to them.

The total cost to the Metropolitan division for the power it will require in 1932, if Niagara power is used, will be $107,651,000. If the growth in energy required between 1930 and 1932 were supplied from new steam-electric plants in the Metropolitan division, the total cost in 1932 would be $110,899,000, showing an annual saving of $3,248,000 in favor of Niagara power. Were the power purchased from the Niagara power interests, the total investment for 1932 would be $5,080,000 less than that required to generate an equal amount by steam.

The use of the St. Lawrence power as suggested above would save 2,234,000 tons of coal annually, and the use of Niagara power in the Metropolitan division as suggested would save 1,204,000 tons of coal annually.

The new power-plant capacity required in the superpower zone would be 3,098,000 kilowatts in 1925 and 4,980,000 kilowatts in 1930.

In Table 76 is shown the cost of power delivered from the new power plants and transmission system of the superpower system for 1930. The lowest rate is that for the Southern division, 6.8 mills per kilowatt-hour; the highest is that for Western New England, 11.4 mills. The average for the whole superpower zone is 8.4 mills. This, however, is the combined rate for power generated in new, large, and highly efficient hydroelectric and steam plants. The true comparison in production costs between the superpower system as of 1930 and independent operation for 1919 is 9.3 mills per kilowatt-hour as against 19.3 mills per kilowatt-hour.

Finally, the appendix shows that in 1930 the cost of the power produced by the superpower system, *inclusive* of fixed charges, as delivered on the busses of the electric utilities, would be 10.6 mills per kilowatt-hour, whereas the cost under independent operation as of 1919, *exclusive* of fixed charges, would be practically the same. This, in my opinion, is the fundamental reason why the expansion of electric utilities should follow the superpower plan.

Appendix F. Steam-electric plants for the superpower system.

Appendix F shows the capacity of the existing plants of the electric utilities to be retained in the superpower system and their location by geographic divisions. The total capacity retained is 2,677,000 kilowatts, which represents 79 per cent of the effective capacity of the steam-electric public utilities in the superpower zone in 1919. The reproduction cost of these plants is $329,219,000.

This appendix presents curves showing the average performance of existing steam plants and of the plants in the superpower system. The character and the design of the base-load steam plants are discussed. The performance of the retained steam plants shows that these should average about 2.15 pounds of coal per kilowatt-hour, as against 2.73 pounds per kilowatt-hour for all electric-utility steam plants operating in the zone in 1919, when both groups are operating at the same annual capacity factor.

The average size of the steam plants retained is 44,600 kilowatts, and the reproduction cost as of 1919 is $124 per kilowatt, as against $109.50 for new steam plants as of 1930. After consultation with many representatives of manufacturers in all parts of the country and with designing and operating engineers, the following operating characteristics for base-load steam plants were determined:

Steam pressure at turbine throttle, 300 pounds per square inch.
Superheat at turbine throttle, 230° F.
Final temperature at turbine throttle, 652° F.
Absolute pressure at turbine exhaust nozzle, 1 inch of mercury.

Of special interest is Table 80, showing summarized estimates of cost for three sizes of base-load steam plants. These estimates were made after consultation with many of the best authorities in power-station design and are considered conservative.

The base-load steam plants for the system will be composed of units of 30,000 kilowatts or multiples thereof, and the largest plant proposed is one of 360,000 kilowatts. These plants will be built in units, and some of them will require the full 10 years for their expansion to complete size. Plate VIII shows the performance for these plants and takes into account such reasonable advances in the art of power production as may be made in 10 years. By 1930 the new steam-electric plants should operate at a capacity factor of about 62 per cent with a fuel rate of 1.43 pounds of coal per kilowatt-hour.

Table 80 shows that the unit investment cost of a base-load steam-electric plant varies but little with size after 120,000 kilowatts has been reached, being only 6.5 per cent less for a 360,000-kilowatt station than for a 120,000-kilowatt station. On the other hand, the unit cost of a 30,000-kilowatt plant is 23 per cent more than that of a 120,000-kilowatt plant.

The proposed new steam-electric plants have been so located as to obtain the fullest advantage of low freight rates, easy coal-delivery routes, and ample condensing water. Fourteen new steam-electric plants, aggregating 2,520,000 kilowatts, will be required by 1925, and four additional plants, or eighteen in all, aggregating 3,930,000 kilowatts, by 1930. The total for 1925 is equivalent to 63 per cent of all the present steam-electric generating capacity in service for the utilities, and that for 1930 to 98 per cent.

In the Anthracite division base-load steam-electric plants, using buckwheat No. 3 coal, can be operated most advantageously because of the combined use of their power for the Metropolitan and Southern divisions. The diversity between these divisions and the Anthracite division will permit operation at a capacity factor of 75 per cent, and under these conditions electric energy can be produced in 1930, inclusive of fixed charges, at 5.7 mills per kilowatt-hour. This figure is sufficiently low to permit the additional fixed charges on transmission for the part of the power that is sent to the tidewater region.

There are three steam-electric power-station sites in the Anthracite region—one near Pittston, one near the mouth of Nescopeck Creek, and one near Sunbury, all in Pennsylvania and all on Susquehanna River—at which sufficient condensing water is available to permit the development of 300,000 kilowatts each.

Appendix G. Hydroelectric plants for the superpower system.

The construction of a hydroelectric plant is economically justified if it produces its power at a cost less than that of a steam-electric plant of the same capacity. With maximum development of water power, however, the hydroelectric energy available within the superpower zone will amount to less than 21 per cent of the total electric power required in 1930.

Of especial importance in determining the location and capacity of the new water-power plants for the zone is the economy attained by the development of rivers beyond their primary power. The dam and headworks of a hydroelectric plant are the principal items of its cost. Additional generating units can be installed at half the cost of providing the same steam-electric capacity, and the construction of storage reservoirs will increase the capacity of the plant above the primary power of the river for effective use under peak loads.

The principal rivers which can contribute water power to the superpower zone are the Potomac, Susquehanna, Delaware, Hudson, and Connecticut. It is proposed to utilize power from these rivers in 1930 to the following extent:

River.	Capacity (kilowatts).	Output (millions of kilowatt-hours).	Investment.	Production cost (mills per kilo-watt-hour).
Potomac	200,000	950	$22,000,000	3.36
Susquehanna	185,000	1,230	28,000,000	3.22
Delaware	350,000	1,250	51,500,000	5.95
Hudson	150,000	900	38,350,000	5.84
Connecticut	165,000	760	29,000.000	5.45

It is proposed to develop these rivers above their primary power capacity for peak-load operation.

The water powers of Niagara and St. Lawrence rivers are within transmission distance of the superpower zone, but on account of the time-required for construction on the St. Lawrence and of the treaty restrictions concerning the use of the water at Niagara Falls the power from these sources has not been considered available in the zone prior to 1930.

Under present construction and operating costs power purchased at Niagara or on St. Lawrence River at $20 a horsepower, ready for transmission at those points at potentials of not less than 220,000 volts, can be placed at Utica and Schenectady, N. Y., and at Northampton, Mass., for 4.6 mills per kilowatt-hour, and at Paterson, N. J., for 5.7 mills. These figures assume purchases of not less than 300,000 kilowatts delivered at a load factor of not less than 80 per cent.

The reproduction cost of the 451,500 kilowatts of existing hydroelectric capacity within the zone is $87,127,000. The new hydroelectric capacity which should be installed by 1930 will bring the total capacity up to 1,501,500 kilowatts, of which the old plants will represent 30 per cent. In 1930 the total hydroelectric investment will be $245,977,000, of which the old plants will represent 35 per cent.

Appendix H. The superpower transmission system.

So far as the existing electric utilities are concerned the superpower system begins and ends at their power-station busses, and so far as the new superpower plants are concerned it begins at these plants and ends on the busses of the existing electric utilities.

In presentations of the superpower plan I have said, "The primaries of to-day will be the secondaries of to-morrow." The existing transmission systems of the electric-utility companies, which comprise about 1,200 miles operated at 33,000 volts or higher, will become distribution rather than transmission systems, and they will of necessity require expansion to distribute the additional power delivered to them from the superpower system. The transmission features of the superpower system will therefore have to do only with the transmission of power from the new plants to load centers and to the busses of the existing electric-utility plants.

In 1930 the superpower transmission system should consist of 970 circuit miles of 220,000-volt lines and 4,696 circuit miles of 110,000-volt interconnecting lines. To these lines will be connected 5,600,000 kilovolt-amperes of transformer capacity, not including the transformer capacity in the base-load steam-electric plants. The construction of the transmission systems for the St. Lawrence and Niagara developments will add 3,140 circuit miles of 220,000-volt lines and 1,824,000 kilovolt-amperes of transformers. Thus potentials of not less than 220,000 volts will be selected to transmit power from plants that are at considerable distances from the general interconnected superpower plants, and within the zone a potential of not less than 110,000 volts will be employed for interconnection between power and load centers. Plates II and III illustrate the proposed transmission arrangements.

In our study of the transmission problem within and without the superpower zone we have been most fortunate in obtaining advice and counsel from most of the high-tension experts of this country. Throughout this study it has been assumed as a necessary condition that the factor of reliability of transmission service for the superpower system must be the same as that of the busses of the power stations themselves. The transmission system has therefore been considered merely as a high-tension extension of those busses.

Appendix I. Reliability of service.

The inherent features of the superpower system themselves constitute adequate provision for reserves throughout its structure.

Appendix J. The relation of coal and coal-delivery routes to the superpower system.

The elements of greatest importance in insuring a continuous supply of power are coal and the routes by which coal is delivered to the superpower stations. Table 97 shows the distribution and use of coal in the superpower zone in 1919.

Plate X shows the available coal-mining districts and the principal rail routes to the proposed base-load steam-electric plants for 1930. This map relates especially to bituminous coal, for the plants that burn anthracite will be built in the anthracite region.

Throughout the study the cost of bituminous coal at the mines has been taken at $2.90 per short ton—the weighted average cost for 1919 to the industries that used bituminous coal. Doubtless labor costs will be reduced, but this reduction will be offset by the necessity of developing deeper mines and thinner seams and of extending underground haulage. The freight rates for 1919 were used in the calculations made for that year, but in the calculations for 1925 and 1930 the freight rates in force January 1, 1921, have been used.

For buckwheat coal used at stations in the anthracite region $1.75 per long ton has been used as the mine price for all periods, with $1 per long ton as the gathering charge.

The cost of coal delivered to the several load centers is shown in Table 98. Naturally these costs have played an important part in determining the location of steam-electric power stations.

Six months' storage capacity for each plant is recommended and would yield obvious advantages. It would absolutely prevent interruption of service due to lack of fuel; it would permit the purchase of coal at the lowest price; and it would help to stabilize the mining and transportation industries by making the demand for coal more uniform.

The question whether the superpower system should own coal mines, coal cars, coal-delivery routes, either or all, has been considered, and it has been concluded that the superpower system should confine its activities to the production of power and the storage of coal.

Appendix K. Use of process fuels and pulverized coal for base-load steam-electric plants.

Under present conditions, in general, coal must be used in raw form to produce cheap power. Coal is treated by certain processes for two purposes—to place its energy in more desirable form and to recover valuable by-products. If power is produced by the use of either coke or gas from process-fuel plants the value of the remaining products, when credited to the cost of such fuels, is not sufficient to reduce their cost below that of raw coal. As certain by-products are essential in time of war regardless of cost, however, it has been deemed desirable in selecting a site for a superpower station to provide space for a processing plant and to adopt a method of boiler-room construction that will permit the use of process fuel if and when its use is found desirable.

Appendix K compares the results of the use at base-load steam-electric plants of process fuels prepared by four methods. Table 99 shows that the cost of fuel prepared by three of the four processes is higher than that of raw coal. Where gas is the process fuel made at by-product coke ovens it is cheaper than raw coal, but the large quantity of coke produced and the difficulty of disposing of it make this process generally impracticable. In certain situations, however, as the appendix points out, if the gas can be sold at a sufficiently high price processing of fuel may be economical.

The greatest promise regarding process fuel lies in the direction of devising plants that will convert raw fuel entirely into gas for consumption under the boilers at steam-electric stations and thus eliminate the enormous concentration of coke. Such a process plant used in combination with a steam-electric plant may produce fuel at a cost materially lower than that of raw coal, but the experimental work done is not yet sufficient to permit a stronger statement than that the progress made is exceedingly encouraging.

Appendix L. Basic costs.

Appendix L, which considers cost of money, depreciation and obsolescence, and taxes and insurance, is so brief that it is in itself a summary. The term "general expense," used in the estimates of cost of power production, includes salaries and expenses of administrative officers, engineers, and legal counsel, salaries of clerks, and expenses covering claims, stationery, printing, etc. Amortization, taxes, and insurance have been included under "fixed charges" rather than in this item.

Figure 61 shows the relation of "general expense" to annual gross revenue. This curve shows the small rate of percentage increase in charge for general expense for revenue above $3,000,000 and the marked increase for revenue less than $3,000,000.

APPENDIX A.

ORGANIZATION.

By W. S. Murray.

In planning this investigation and effecting its organization it was clear that the power market to be served by the proposed superpower system would be divided between the electric utilities, the railroads, and the isolated industrial establishments. Accordingly, Mr. Lorin E. Imlay, Dr. Cary T. Hutchinson, and Mr. Henry W. Butler were recommended and appointed, respectively, as division engineers in charge of the departments of power and transmission, of railroads, and of industries.

Associated with the division engineers as assistants, with duties so shifted as to maintain the highest engineering load factor in the work, were Messrs. Harold Goodwin, jr., Malcolm MacLaren, Norman C. McPherson, E. M. Newlin, B. J. Peterson, T. B. Rutherford, Arthur R. Wellwood, and Lyle A. Whitsit. I desire to make special mention of the able services rendered by these men.

Mr. N. C. Grover, chief hydraulic engineer of the United States Geological Survey, and Mr. O. P. Hood, chief mechanical engineer of the United States Bureau of Mines, were detailed for advisory service on the engineering staff. Mr. Grover, in addition to serving in his capacity as hydraulic engineer, rendered much assistance in administrative work, and Mr. Hood especially studied the problems pertaining to the use of process fuels.

That the work in all departments might be completely coordinated a principal assistant, charged with the assembling of all data and the preliminary preparation of the text of the report, was imperatively needed, and for this responsible duty Mr. Henry Flood, jr., was appointed, with the title of engineer-secretary. The duty of the engineer-secretary included the checking and coordination of the information collected for the several appendixes, and the speed of its collection or compilation for any particular appendix was increased or slackened, as occasion might require, to make it fit in with the rest, so that the report as a whole could be completed on time.

An advisory board was selected, consisting of the following members:

Lester P. Breckenridge (chairman), professor of mechanical engineering, Yale University, New Haven, Conn.; representing fuel engineering.

Magnus W. Alexander, managing director, National Industrial Conference Board, Boston, Mass.; representing National Industrial Conference Board.

Edward G. Buckland, vice president New York, New Haven & Hartford Railroad Co., New Haven, Conn.; representing New England railroads.

Charles L. Edgar, president Edison Electric Illuminating Co. of Boston, Boston, Mass.; representing National Electric Light Association.

Abraham T. Hardin, vice president New York Central Railroad Co., New York City; representing New York railroads.

Herbert Hoover, now Secretary of Commerce, Washington, D. C.; when appointed, president American Institute of Mining and Metallurgical Engineers; representing the mining industry.

William Kelly, Colonel, United States Army, Washington, D. C.; representing the War Department.

Elisha Lee, vice president Pennsylvania Railroad Co., Philadelphia, Pa.; representing railroads south of New York.

Arthur D. Little, president of Arthur D. Little, Inc., Cambridge, Mass.; representing electro-chemical and by-products industries.

James H. McGraw, president McGraw-Hill Co., Inc., New York City; representing the technical press.

John H. Pardee, president J. G. White Management Corporation, New York City; representing American Electric Railway Association.

Henry C. Perkins, mining engineer, Washington, D. C.; representing the mining industry.

Matthew S. Sloan, president Brooklyn Edison Co., Brooklyn, N. Y.; representing National Electric Light Association.

During the year eight meetings of the advisory board were held, and for the counsel and advice offered by its members I now express my most sincere appreciation.

Prof. L. P. Breckinridge, chairman of the advisory board, who has been constant in attendance at the meetings of the board and at many of the meetings of the engineering staff, has been encouragement personified and with his circumspection and his ability as a leader in the solution of the fuel problem has been of invaluable assistance.

I believe I can say without contradiction that the engineering staff is a unit in the findings of this report, and I can find no words to express fitly the tribute I owe these men for their loyalty and their able assistance.

The engineering staff, for all the members of which I speak, are especially grateful to the experts mentioned in the following list. To them apparently came the sense of responsibility of contributing their experience to the fullest where it was required. They made it apparent to me that I could call on them exhaustively, for they realized the national importance of this problem. Many, therefore, have been the consultations held with them, and their advice is reflected in the pages of this report.

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A host of others, engineers and business men, contributed most valuable and pertinent information to this work, and I wish to make here the most grateful recognition of their services. The names of these coworkers follow, classified as to the nature of the information furnished:

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George Gibbs, consulting engineer, New York.
Edwin B. Katte, director electric traction, New York Central Railroad Co., New York City.
M. W. Manz, development engineer, Ohio Brass Co., Barberton, Ohio.
C. H. Quinn, electrical engineer, Norfolk & Western Railway Co., Roanoke, Va.
J. T. Wallis, chief of motive power, Pennsylvania System, Altoona, Pa.

Law and finance.

H. M. Addinsell, Harris Forbes & Co., New York.
A. E. Barrows, president, Narragansett Lighting Co., Providence, R. I.
T. R. Beal, president, Central Hudson Gas & Electric Co., Poughkeepsie, N. Y.
A. W. Burchard, vice president, General Electric Co., New York.
Frederick Darlington, Westinghouse Electric & Manufacturing Co., New York.

F. M. Feiker, Assistant to the Secretary of Commerce, Washington, D. C.
H. I. Harriman, president, New England Power Co., Boston, Mass.
John Price Jackson, Ardmore, Pa.
John W. Lieb, vice president, New York Edison Co., New York.
Joseph B. McCall, president, Philadelphia Electric Co., Philadelphia, Pa.
Thomas M. McCarter, president, Public Service Electric Co., Newark, N. J.
D. E. Manson, vice president, Charles H. Tenney & Co., Boston, Mass.
S. Z. Mitchell, president, Electric Bond & Share Co., New York.
Thomas E. Murray, president, Thomas E. Murray (Inc.), New York.
E. W. Rice, president, General Electric Co., New York.
James Sheldon, Lee Higginson & Co., New York.
Guy E. Tripp, chairman board of directors, Westinghouse Electric & Manufacturing Co., New York.
Herbert Wagner, president, Consolidated Gas, Electric Light & Power Co., Baltimore, Md.
O. D. Young, vice president, General Electric Co., New York.

An appropriation of $250,000 was requested to cover the investigation and report. Congress appropriated $125,000, with the proviso that additional funds could be subscribed by the parties in interest. The electric utilities, industries, and railroads rendered so much valuable engineering assistance that the additional amount required to complete the investigation and report was only $26,000. This amount was subscribed by the electric public utilities and manufacturers within the zone, and its welcome receipt is now gratefully acknowledged. The sum of $25,000 of the Federal appropriation was expended "for a survey of power production and distribution in the United States" in accordance with the terms of the appropriating act.

In concluding this investigation I wish to say that when I was asked by the Secretary of the Interior to accept the chairmanship of the superpower survey I did so with the predominating thought that a large responsibility would be attached to the authorship of the report to be prepared, and that in this great work no one man should assume that responsibility. Nothing can so surely bring success to an enterprise of this kind as its prosecution under the concordant action of a large number of minds. The estimate of the saving to be effected by the superpower system in 1930 is based upon the cost of power production in 1919, and we have no doubt that it can be made. We also agree that much of this saving can be made through the natural expansion of the electric public utilities, but if these utilities, which are the only instrumentalities through which maximum economy can be attained, will cooperate 100 per cent to the end that a coordinated expansion through interconnecting systems of transmission and distribution circuits shall be made, then the shortest route to a maximum national conservation of money, labor, and material will have been mapped out. To show that such a project is feasible and would be profitable was the task that confronted my organization on July 1, 1920.

APPENDIX B.

ELECTRIC UTILITIES IN INDEPENDENT OPERATION IN THE SUPERPOWER ZONE IN 1919.

By L. E. Imlay, T. B. Rutherford, and others of the engineering staff.

DEMAND AND OUTPUT.

Table 1 shows the distribution of load, the demand, and the requirements of energy for electric utilities in the superpower zone in 1919 and the frequencies in use.

Table 1.—*Distribution of load, by geographic divisions and load centers, for electric utilities in the superpower zone in 1919.*

Geographic division and load center.	Maximum demand (thousands of kilowatts).				Energy output (millions of kilowatt-hours).			
	25 cycles.	60 cycles.	Other frequencies.	Total.*	25 cycles.	60 cycles.	Other frequencies.	Total.
Eastern New England:								
Boston	68.06	122.14	52.96	243.16	240.18	380.72	151.77	772.67
Lowell	4.56	62.18	1.82	68.56	13.85	176.05	7.11	197.01
Providence	25.80	128.95	6.02	160.77	65.87	370.27	14.66	450.80
Worcester	11.00	86.81	2.52	100.33	30.60	314.24	7.09	351.93
	109.42	400.08	63.32	572.82	350.50	1,241.28	180.63	1,772.41
Western New England:								
Hartford	6.60	50.47	3.98	61.05	26.02	133.66	7.87	167.55
New Haven	33.68	90.47	21.06	145.21	133.00	248.30	54.77	436.07
Northampton	4.60	94.04	9.23	107.87	14.14	293.64	10.59	318.37
	44.88	234.98	34.27	314.13	173.16	675.60	73.23	921.99
Mohawk:								
Utica	1.57	25.36	.14	27.07	5.86	78.02	.37	84.25
Schenectady	13.10	8.50	87.20	108.80	30.92	28.02	294.97	353.91
	14.67	33.86	87.34	135.87	36.78	106.04	295.34	438.16
Metropolitan:								
Newark	27.00	154.18	12.14	193.32	121.27	594.26	15.64	731.17
New York	809.00	148.79	13.89	971.68	2,648.99	477.34	9.17	3,135.50
	836.00	302.97	26.03	1,165.00	2,770.26	1,071.60	24.81	3,866.67
Hudson:								
Poughkeepsie	0	20.05	1.45	21.50	0	59.33	1.15	60.48
	0	20.05	1.45	21.50	0	59.33	1.15	60.48
Anthracite:								
Allentown	35.28	35.40	1.14	71.82	180.70	148.53	2.47	331.70
Pottsville	0	13.60	1.10	14.70	0	38.90	3.30	42.20
Wilkes-Barre	14.77	79.48	4.31	98.56	43.99	309.16	16.01	369.16
	50.05	128.48	6.55	185.08	224.69	496.59	21.78	743.06
Southern:								
Trenton	2.35	10.03	3.70	16.08	7.64	26.60	10.30	44.54
Harrisburg	.88	69.72	6.09	76.69	3.87	234.91	20.67	259.45
Philadelphia	107.70	241.88	19.25	368.83	365.31	848.32	66.11	1,279.74
Baltimore	111.57	2.54	17.88	131.99	669.52	7.37	3.53	680.42
Washington	66.50	0	.60	67.10	231.71	0	2.50	234.21
	289.00	324.17	47.52	660.69	1,278.05	1,117.20	103.11	2,498.36
Superpower zone	1,344.02	1,444.59	266.48	3,055.09	4,833.44	4,767.64	700.05	10,301.13

DISTRIBUTION OF POWER.

Figure 1 shows the electric-utility load at all the load centers in the superpower zone in 1919. A study of this load chart in combination with the analysis of load growth (p. 34) brings out the striking fact that the power required in 1930, the greater part of which will be applied to industrial uses, will be 2½ times that required to-day.

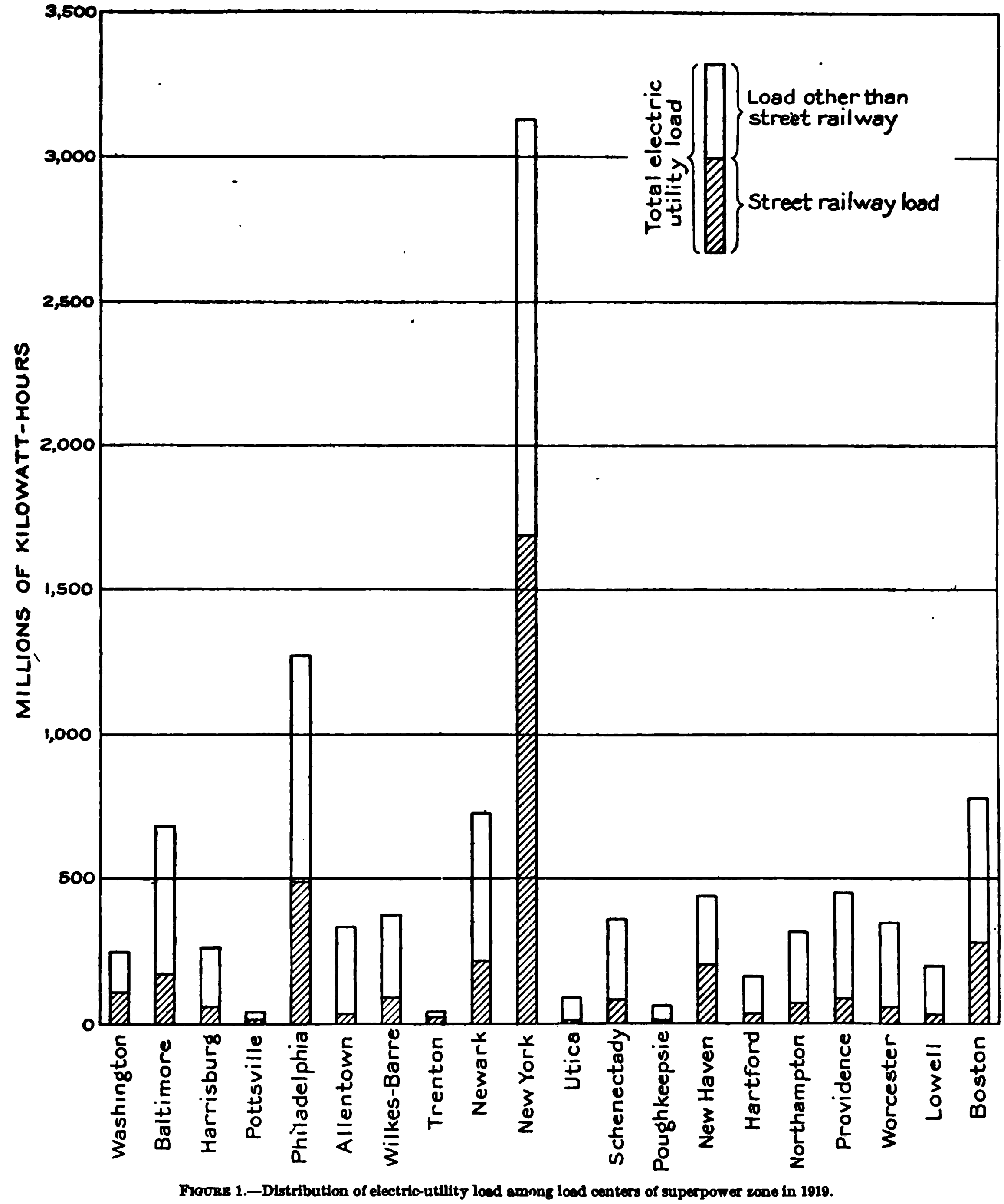


FIGURE 1.—Distribution of electric-utility load among load centers of superpower zone in 1919.

More than 50 per cent of the power generated at the present New York load center is used by the electric railways, whose slower rate of growth of load as compared with that in power for domestic and industrial uses will have the effect of decentralizing the total load on the superpower system by 1930. This effect is shown in Appendix E. The superpower system will become a means to this end.

PAST AND ESTIMATED FUTURE GROWTH OF LOAD.

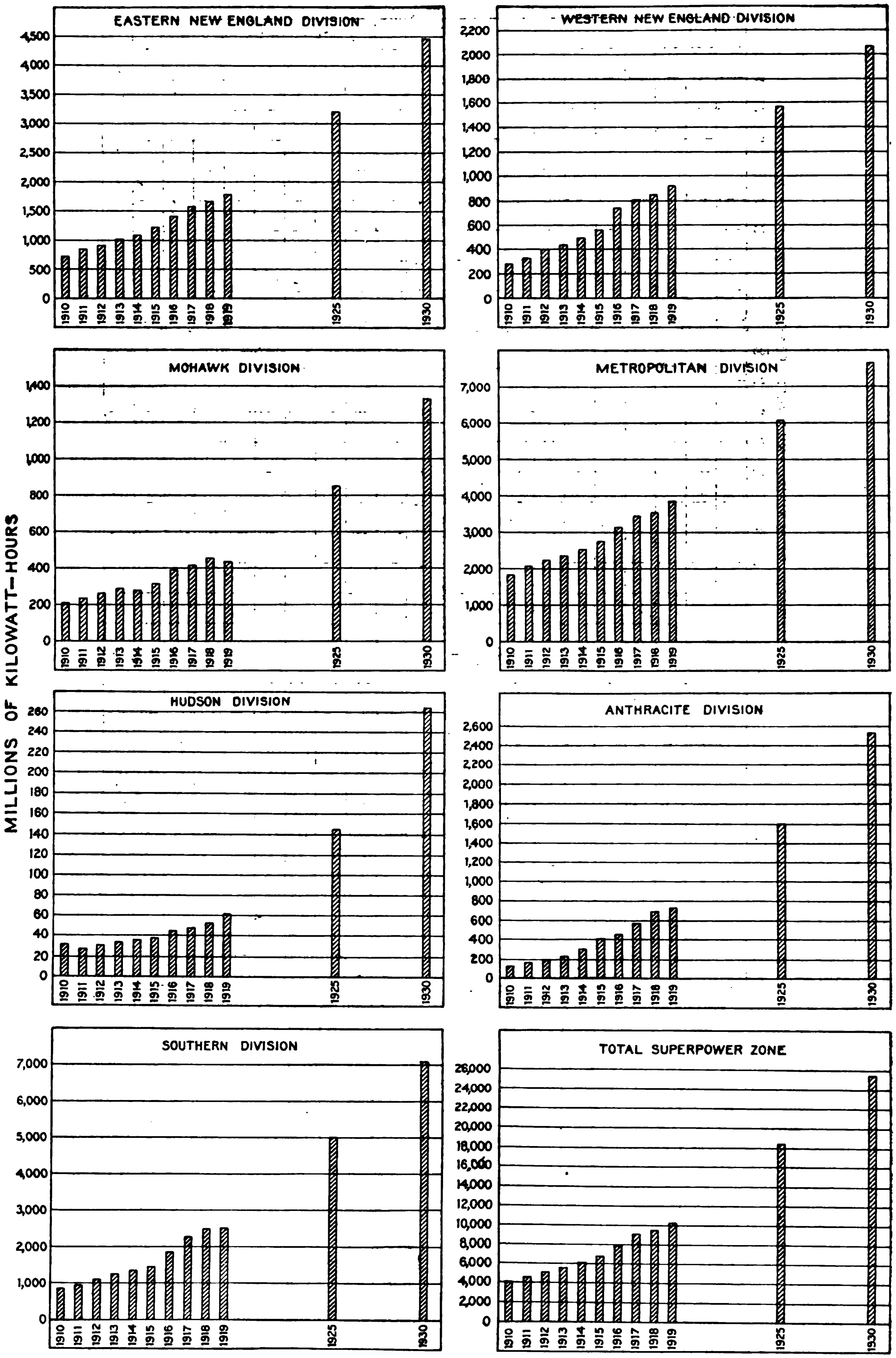
Plate IV shows the growth of the electric-utility industry by geographic divisions and for the entire superpower zone during the 10 years ending with 1919 and the estimated growth by 1925 and 1930. The record of the past growth includes the energy used for lighting, industrial power, electric street railways, and the electrified heavy-traction railroads. The estimate of the future growth does not include demands that may arise from the electrified heavy-traction systems.

The future rate of load growth is estimated at 8.6 per cent, compounded annually. This estimate is based upon the projection of past load growths taken in combination with opinions expressed by the operators of the electric-utility properties. The average annual growth during the last 10 years was 9 per cent.

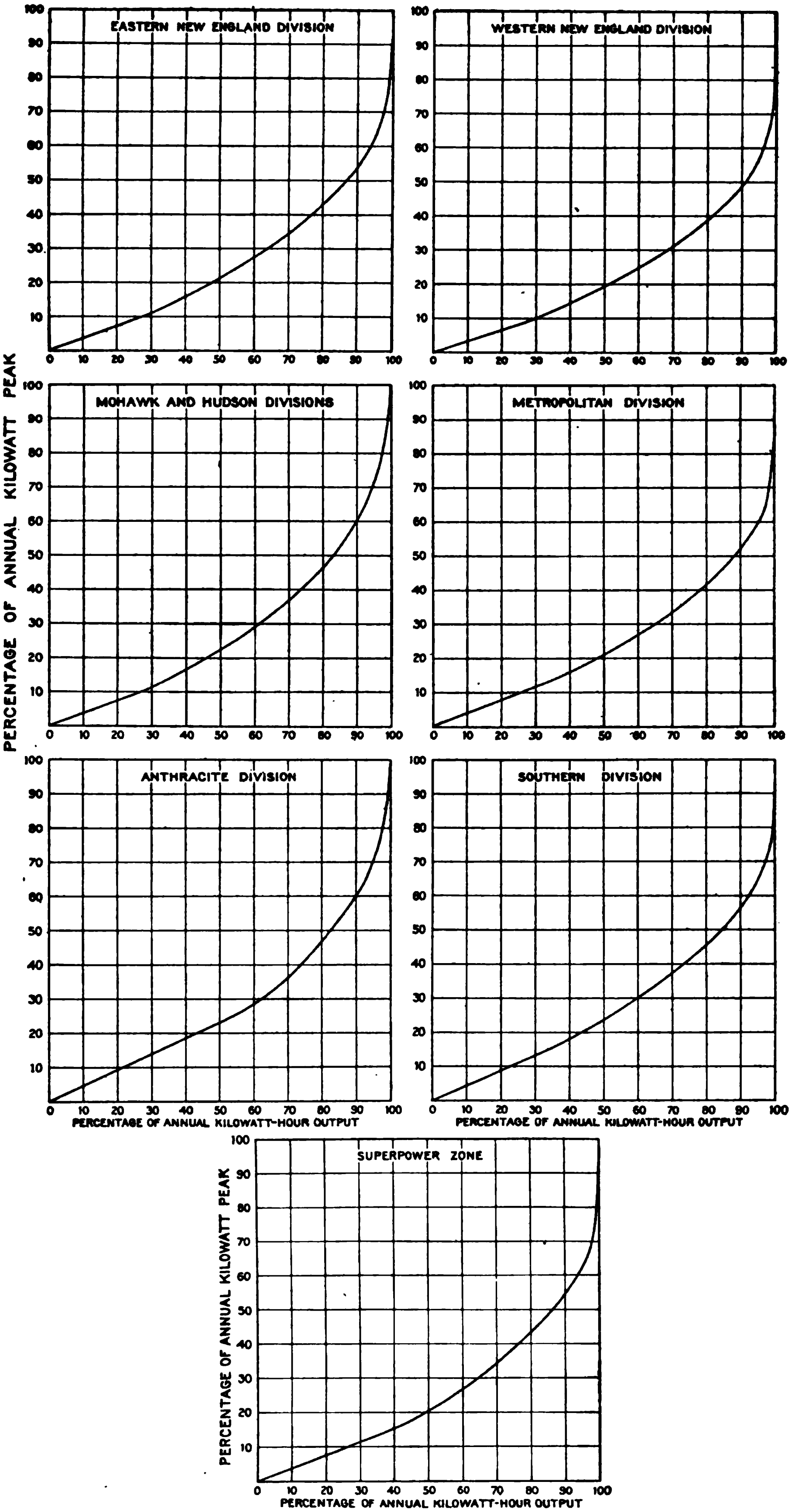
LOADS CARRIED.

Figures 2–8, which are plotted from data furnished by the electric public-utility companies in the superpower zone, show the typical week-day, Saturday, and Sunday loads and also the demand for the day of peak load in 1919.

Plate V shows the relation of energy generated in kilowatt-hours to the demand in kilowatts for the several geographic divisions of the superpower zone in 1919. They show that only about 14 per cent of the energy generated in the zone is produced by the last 50 per cent of the demand. This indicates that the peak load should be carried by the less efficient steam-electric plants and by overdeveloped hydroelectric plants, because when the dam and headworks of a hydroelectric plant are once installed the cost of the generating apparatus for the plant is only half that of the total cost of a steam-electric plant.



PAST AND ESTIMATED FUTURE GROWTH OF LOAD OF ELECTRIC PUBLIC UTILITIES IN SUPERPOWER ZONE, 1910-1930.



DISTRIBUTION OF LOAD FOR ELECTRIC PUBLIC UTILITIES IN SUPERPOWER ZONE IN 1919.

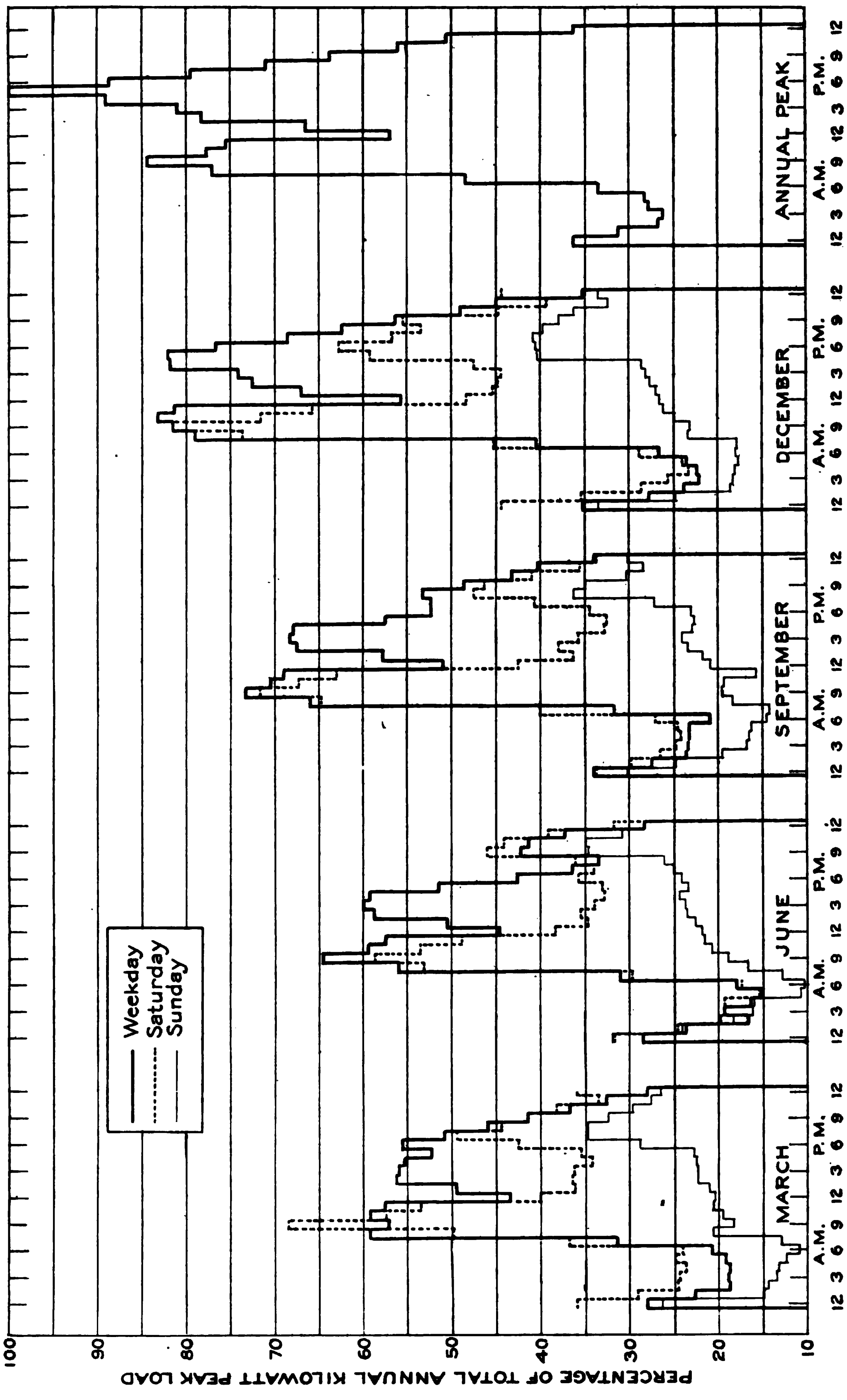


FIGURE 2.—Typical seasonal loads of electric utilities in Eastern New England division in 1919.

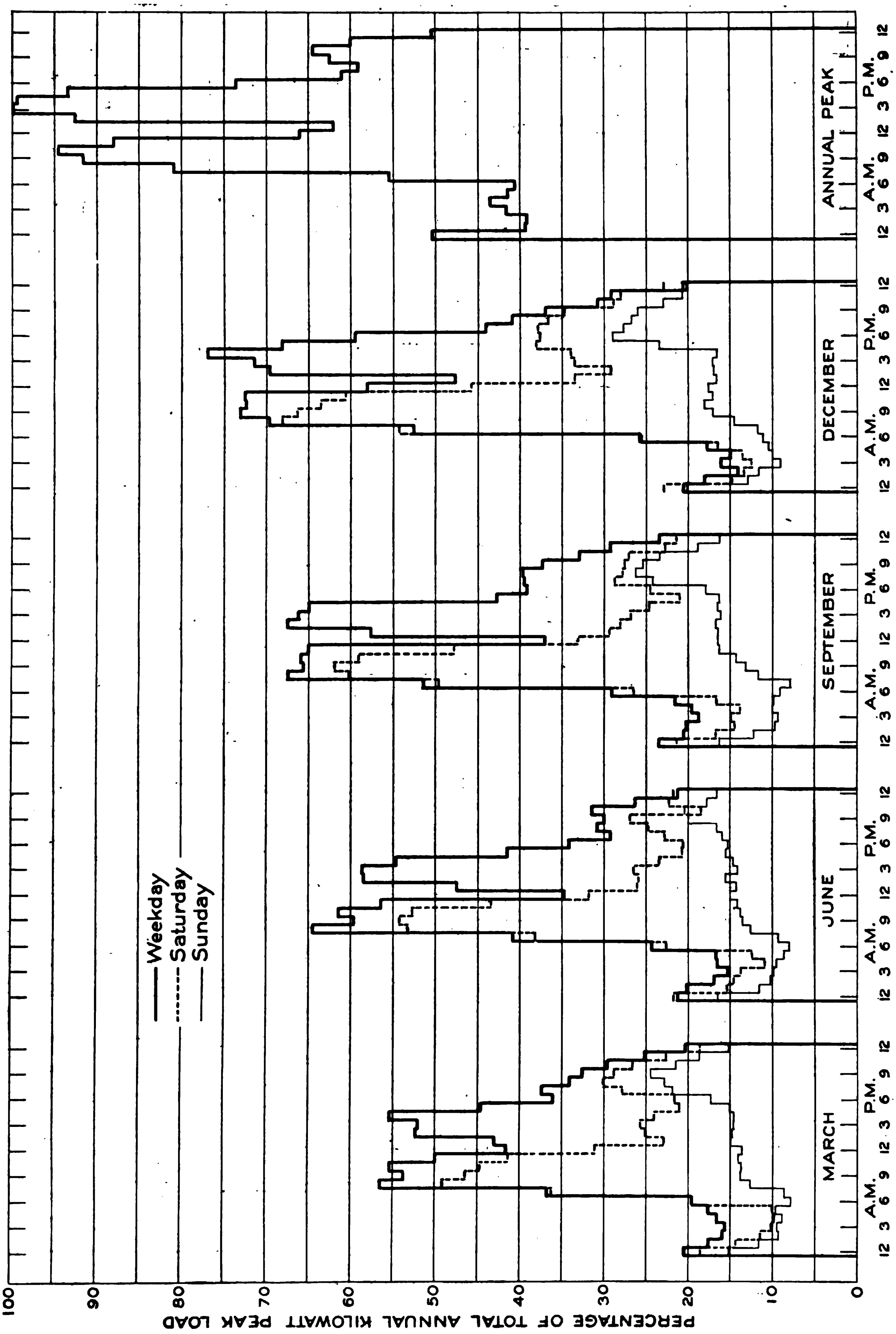


FIGURE 3.—Typical seasonal loads of electric utilities in Western New England division in 1919.

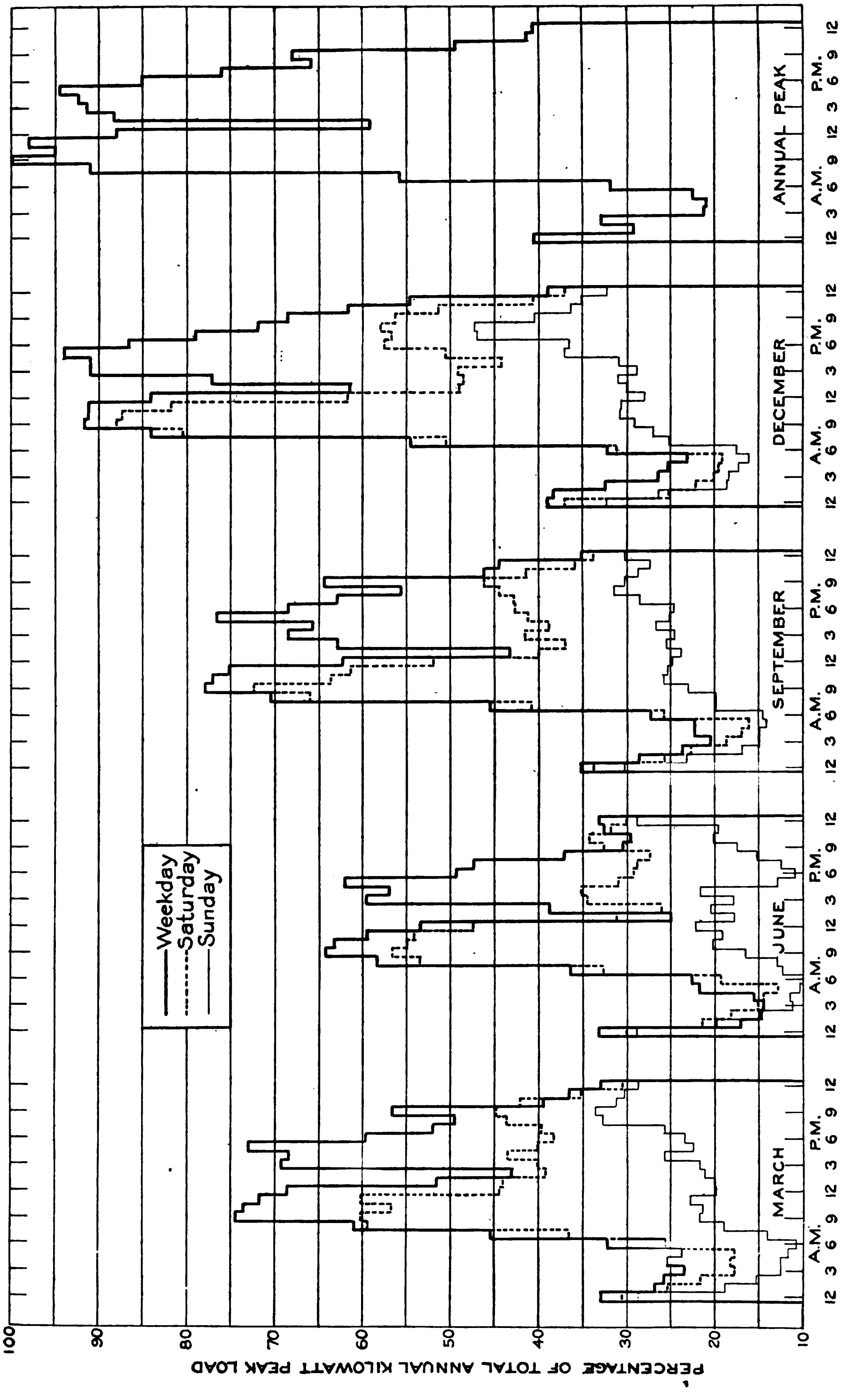


FIGURE 4.—Typical seasonal loads of electric utilities in Mohawk and Hudson divisions in 1919.

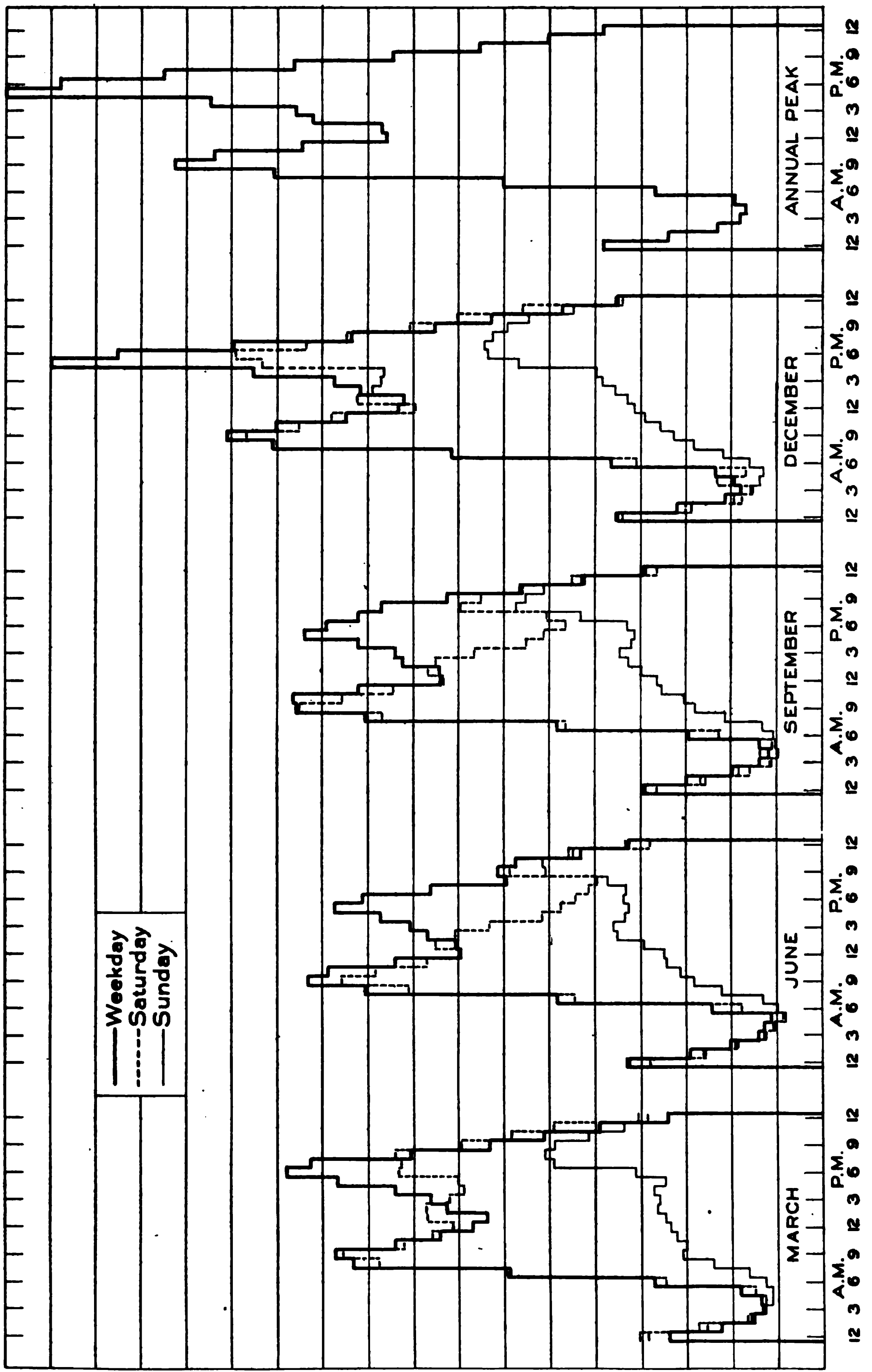


FIGURE 5.—Typical seasonal loads of electric utilities in Metropolitan division in 1919.

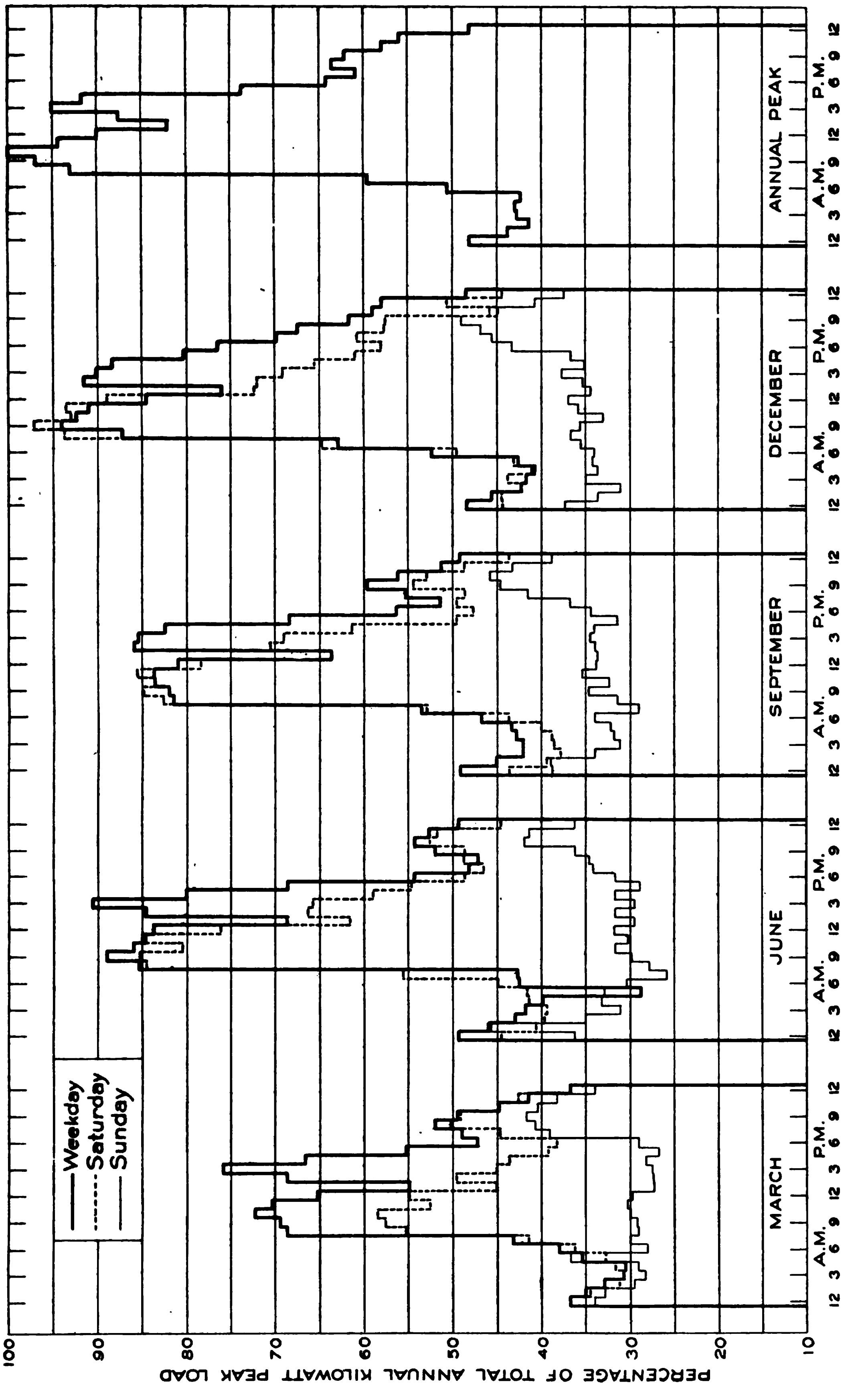


FIGURE 6.—Typical seasonal loads of electric utilities in Anthracite division in 1919.

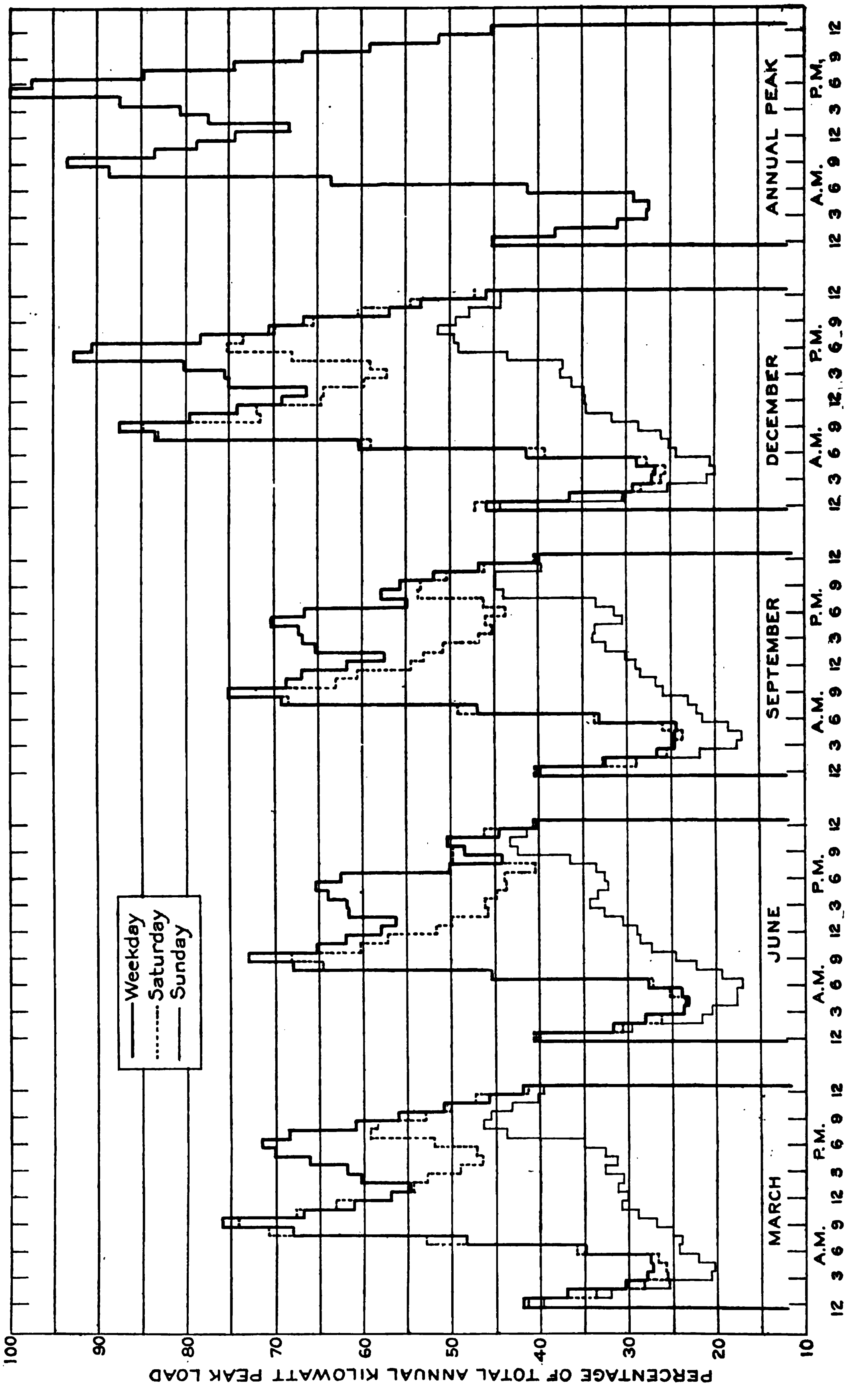


FIGURE 7.—Typical seasonal loads of electric utilities in Southern division in 1919.

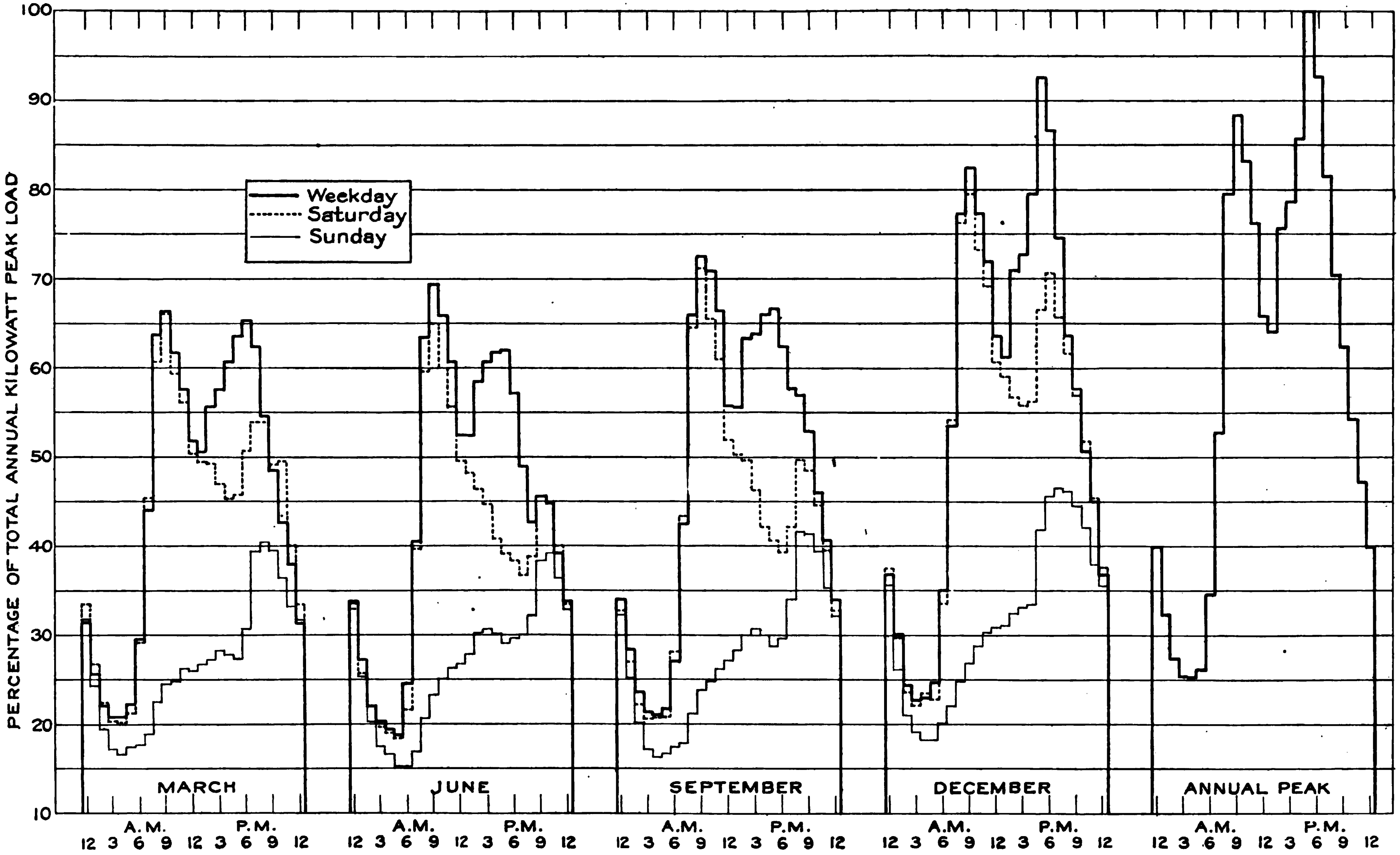


FIGURE 8.—Typical seasonal loads of electric utilities in superpower zone in 1919.

CAPACITY AND NUMBER OF POWER PLANTS.

Table 2 shows the capacity of power plants in the superpower zone, classified into steam-electric and hydroelectric and as to frequency.

TABLE 2.—*Capacity of steam-electric and hydroelectric power plants of electric utilities in the superpower zone in 1919.*

Geographic division and load center.	Steam-electric capacity (thousands of kilowatts).				Hydroelectric capacity (thousands of kilowatts).				Total capacity (thousands of kilowatts).
	25 cycles.	60 cycles.	Other frequencies.	Total.	25 cycles.	60 cycles.	Other frequencies.	Total.	
Eastern New England:									
Boston	131.80	184.78	76.63	393.21	0	5.70	0	5.70	398.91
Lowell	5.50	72.00	3.17	80.67	0	17.88	0.08	17.96	98.63
Providence	42.35	196.84	13.55	252.74	0	1.75	0	1.75	254.49
Worcester	10.00	76.83	2.25	89.08	8.60	61.58	0.41	70.59	159.67
	189.65	530.45	95.60	815.70	8.60	86.91	0.49	96.00	911.70
Western New England:									
Hartford	6.70	43.48	4.65	54.83	0	13.35	0	13.35	68.18
New Haven	51.95	131.17	22.99	206.11	.60	29.93	.57	31.10	237.21
Northampton	13.00	88.39	7.12	108.51	0	65.69	1.39	67.08	175.59
	71.65	263.04	34.76	369.45	.60	108.97	1.96	111.53	480.98
Mohawk:									
Utica	1.75	16.54	0	18.29	2.54	22.20	.12	24.86	43.15
Schenectady	7.00	1.88	31.10	39.98	7.29	10.02	73.98	91.29	131.27
	8.75	18.42	31.10	58.27	9.83	32.22	74.10	116.15	174.42
Metropolitan:									
Newark	38.35	204.71	16.90	259.96	0	8.13	.03	8.16	268.12
New York	1,110.60	242.73	16.53	1,369.86	0	.55	0	.55	1,370.41
	1,148.95	447.44	33.43	1,629.82	0	8.68	.03	8.71	1,638.53
Hudson:									
Poughkeepsie	0	25.82	1.01	26.83	0	8.69	0	8.69	35.52
	0	25.82	1.01	26.83	0	8.69	0	8.69	35.52
Anthracite:									
Pottsville	0	14.19	2.31	16.50	0	.14	0	.14	16.64
Allentown	37.20	42.25	1.55	81.00	0	2.51	0	2.51	83.51
Wilkes-Barre	19.45	91.25	9.61	120.31	0	2.43	0	2.43	122.74
	56.65	147.69	13.47	217.81	0	5.08	0	5.08	222.89
Southern:									
Trenton	2.10	15.14	5.83	23.07	.75	0	0	.75	23.82
Harrisburg	0	68.50	7.17	75.67	.88	15.82	0	16.70	92.37
Philadelphia	151.80	295.74	34.00	481.54	2.70	.65	.03	3.38	484.92
Baltimore	191.00	4.93	6.60	202.53	84.10	.41	0	84.51	287.04
Washington	98.00	0	1.57	99.57	0	0	0	0	99.57
	442.90	384.31	55.17	882.38	88.43	16.88	.03	105.34	987.72
Superpower zone	1,918.55	1,817.17	264.54	4,000.26	107.46	267.43	76.61	451.50	4,451.76

Figure 9 shows the number of power plants of different generator capacities among 280 of the larger electric-utility plants in the superpower zone in 1919. The average size of plant for all the utilities was 7,900 kilowatts, and there were 104 plants of this or greater capacity.

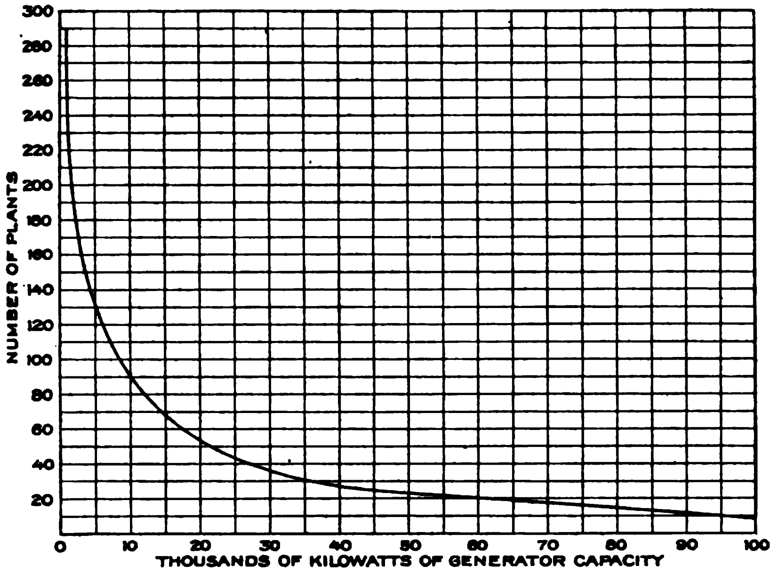


FIGURE 9.—Number of generating plants of different capacities owned by 280 of the electric-utility companies in the superpower zone in 1919.

Figure 10 shows the number of generating units of different sizes among 1,074 units of 500 kilowatts or more in the superpower zone in 1919. The average size of unit for all the utilities was 2,700 kilovolt-amperes, and the number of units of this size or greater capacity was 420. The capacity of the units to be installed in future superpower plants will be more than three times that of the plant of average size now in the zone.

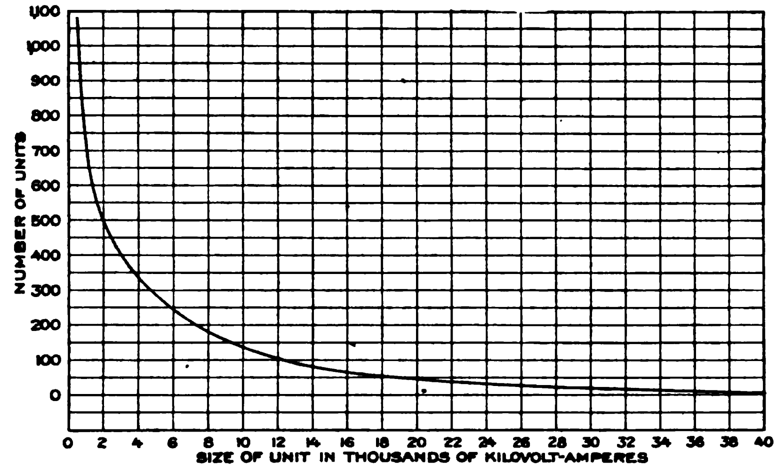


FIGURE 10.—Number of generating units of different sizes over 500 kilowatts owned by the electric-utility companies in the superpower zone in 1919.

PERFORMANCE.

Table 3 shows the performance of 400 steam-electric and 158 hydroelectric power plants in the superpower zone in 1919. The effective capacity of steam-electric plants, though not of hydroelectric plants, is usually less than their generator capacity, being generally limited by boiler capacity.

TABLE 3.—*Character and performance of electric-utility plants in the superpower zone in 1919.*

Geographic division and load center.	Existing generating plants.			Generator capacity (thousands of kilowatts).			Effective capacity (thousands of kilowatts).		
	Steam-electric.	Hydro-electric.	Total.	Steam-electric plants.	Hydro-electric plants.	Total.	Steam-electric plants.	Hydro-electric plants.	Total.
Eastern New England:									
Boston	34	1	35	393. 21	5. 70	398. 91	321. 95	5. 70	327. 65
Lowell	25	15	40	80. 67	17. 96	98. 63	75. 23	17. 96	93. 19
Providence	19	1	20	252. 74	1. 75	254. 49	190. 63	1. 75	192. 38
Worcester	8	10	18	89. 08	70. 59	159. 67	64. 38	70. 59	134. 97
	86	27	113	815. 70	96. 00	911. 70	652. 19	96. 00	748. 19
Western New England:									
Hartford	12	6	18	54. 83	13. 35	68. 18	53. 56	13. 35	66. 91
New Haven	24	10	34	206. 11	31. 10	237. 21	174. 63	31. 10	205. 73
Northampton	16	22	38	108. 51	67. 08	175. 59	91. 05	67. 08	158. 13
	52	38	90	369. 45	111. 53	480. 98	319. 24	111. 53	430. 77
Mohawk:									
Utica	16	18	34	18. 29	24. 86	43. 15	17. 79	24. 86	42. 65
Schenectady	14	27	41	39. 98	91. 29	131. 27	38. 10	91. 29	129. 39
	30	45	75	58. 27	116. 15	174. 42	55. 89	116. 15	172. 04
Metropolitan:									
Newark	25	8	33	259. 96	8. 16	268. 12	223. 71	8. 16	231. 87
New York	53	2	55	1, 369. 86	. 55	1, 370. 41	1, 119. 05	. 55	1, 119. 60
	78	10	88	1, 629. 82	8. 71	1, 638. 53	1, 342. 76	8. 71	1, 351. 47
Hudson:									
Poughkeepsie	13	13	26	26. 83	8. 69	35. 52	23. 11	8. 69	31. 80
	13	13	26	26. 83	8. 69	35. 52	23. 11	8. 69	331. 80
Anthracite:									
Pottsville	11	0	11	16. 50	. 14	16. 64	13. 20	. 14	13.34
Allentown	6	6	12	81. 00	2. 51	83. 51	75. 50	2. 51	78. 01
Wilkes-Barre	23	4	27	120. 31	2. 43	122. 74	107. 40	2. 43	109. 83
	40	10	50	217. 81	5. 08	222. 89	196. 10	5. 08	201. 18
Southern:									
Trenton	16	1	17	23. 07	. 75	23. 82	18. 05	. 75	18. 80
Harrisburg	17	6	23	75. 67	16. 70	92. 37	65. 20	16. 70	81. 90
Philadelphia	51	4	55	481. 54	3. 38	484. 92	422. 86	3. 38	426. 24
Baltimore	14	4	18	202. 53	84. 51	287. 04	185. 30	84. 51	269. 81
Washington	3	0	3	99. 57	0	99. 57	99. 57	. 00	99. 57
	101	15	116	882. 38	105. 34	987. 72	790. 98	105. 34	896. 32
Superpower zone	400	158	558	4, 000. 26	451. 70	4, 451. 76	3, 380. 27	451. 50	3, 831. 77

TABLE 3.—*Character and performance of electric-utility plants in the superpower zone in 1919*—Continued.

Geographic division and load center.	Generator reserve in steam-electric plants.		Effective reserve in steam-electric plants.		Generated output (millions of kilowatt-hours).			Annual effective capacity factor (per cent).		
	Total (thousands of kilowatts).	Per cent.	Total (thousands of kilowatts).	Per cent.	Steam-electric plants.	Hydroelectric plants.	Total.	Steam-electric plants.	Hydro-electric plants.	Total.
Eastern New England:										
Boston	136. 41	53. 1	65. 15	25. 4	759. 16	13. 52	772. 68	26. 9	27. 1	26. 9
Lowell	30. 06	59. 2	24. 62	48. 7	143. 81	53. 20	197. 01	21. 8	33. 8	24. 1
Providence	91. 90	57. 2	29. 79	18. 5	445. 79	5. 00	450. 79	26. 7	32. 6	26. 7
Worcester	30. 35	51. 7	5. 65	9. 6	131. 11	220. 82	351. 93	23. 3	35. 7	29. 8
	288. 72	54. 8	125. 21	23. 8	1, 479. 87	292. 54	1, 772. 41	25. 9	34. 8	27. 1
Western New England:										
Hartford	6. 74	14. 0	5. 48	11. 4	115. 22	52. 33	167. 55	24. 5	44. 7	28. 6
New Haven	70. 80	52. 3	39. 32	29. 0	379. 58	56. 49	436. 07	24. 8	20. 7	24. 2
Northampton	40. 78	60. 2	23. 32	34. 4	123. 74	194. 63	318. 37	15. 5	33. 1	23. 0
	118. 32	47. 2	68. 12	27. 2	618. 54	303. 45	921. 99	22. 1	31. 1	24. 5
Mohawk:										
Utica	2. 18	13. 5	1. 68	10. 4	17. 42	66. 83	84. 25	11. 2	30. 6	22. 6
Schenectady	18. 83	89. 1	16. 95	80. 2	30. 33	323. 58	353. 91	9. 1	40. 5	31. 1
	21. 01	56. 5	18. 63	50. 0	47. 75	390. 41	438. 16	9. 7	38. 3	29. 1
Metropolitan:										
Newark	152. 02	73. 3	15. 77	7. 5	707. 82	23. 35	731. 17	36. 2	32. 6	36. 0
New York	353. 06	34. 8	102. 25	10. 0	3, 134. 15	1. 35	3, 135. 50	32. 1	28. 0	32. 1
	405. 08	33. 1	118. 02	9. 6	3, 841. 97	24. 70	3, 866. 67	32. 6	32. 3	32. 6
Hudson:										
Poughkeepsie	10. 28	62. 0	6. 56	39. 7	37. 68	22. 80	60. 48	18. 6	30. 0	21. 6
	10. 28	62. 0	6. 56	39. 7	37. 68	22. 80	60. 48	18. 6	30. 0	21. 6
Anthracite:										
Pottsville	1. 80	12. 2	0.	0	42. 17	. 03	42. 20	36. 4	24. 4	36. 1
Allentown	1. 63	2. 0	0.	0.	317. 98	13. 72	331. 70	48. 0	62. 4	48. 5
Wilkes-Barre	18. 40	18. 0	5. 49	5. 4	365. 69	3. 47	369. 16	38. 8	16. 3	38. 4
	21. 83	11. 1	5. 49	2. 8	725. 84	17. 22	743. 06	42. 2	38. 6	42. 2
Southern:										
Trenton	7. 74	50. 5	2. 62	17. 1	41. 87	2. 67	44. 54	26. 4	40. 6	27. 1
Harrisburg	16. 33	27. 6	5. 86	9. 9	175. 65	83. 80	259. 45	30. 7	57. 3	36. 1
Philadelphia	81. 48	20. 4	22. 8	5. 7	1, 259. 10	20. 64	1, 279. 74	34. 0	69. 7	34. 2
Baltimore	106. 50	111. 0	89. 27	93. 0	175. 46	504. 96	680. 42	10. 8	68. 2	28. 8
Washington	33. 19	50. 0	33. 19	50. 0	234. 21	. 00	234. 21	26. 9	. 0	26. 9
	245. 24	38. 5	153. 84	24. 2	1, 886. 29	612. 07	2, 498. 36	27. 2	66. 2	31. 7
Superpower zone	1, 110. 49	38. 4	490. 50	17. 0	8, 637. 94	1, 663. 19	10, 301. 13	29. 1	42. 2	30. 7

A study of 196 steam-electric plants that use bituminous coal was made to ascertain their performance. These plants were selected from the 400 plants in the superpower zone because full and consistent data were available from each plant. Table 4 is a summary of the results of this study. The fuel consumption varies from 6.23 pounds per kilowatt-hour for the small plants to 2.14 pounds per kilowatt-hour for plants having a capacity of more than 100,000 kilowatts. Perhaps even more striking is the variation in the cost of maintenance, labor, and supplies, for this cost amounts to $23.10 per kilowatt-year of effective capacity for small plants but only to $5.46 for plants of more than 100,000 kilowatts.

The complete result of this study is given in figures 11 and 12, showing the performance and the operating cost, except the cost of fuel, which varies with size of plant, size of unit, and annual capacity factor.

Table 4.—*Performance and operating cost of 196 selected electric plants using bituminous coal in the superpower zone in 1919, by size of plant.*

	Under 1,000 kilowatts.	1,000 to 2,500 kilowatts.	2,500 to 5,000 kilowatts.	5,000 to 10,000 kilowatts.	10,000 to 25,000 kilowatts.	25,000 to 50,000 kilowatts.	50,000 to 100,000 kilowatts.	Over 100,000 kilowatts.	All plants.
Number of plants	33	36	32	29	31	14	13	8	196
Total generator capacity, kilowatts	23,485	62,061	121,575	230,500	507,675	476,100	905,400	1,318,600	3,645,396
Total effective capacity, kilowatts	21,530	54,308	106,200	202,875	449,597	393,600	721,000	1,048,450	3,000,560
Total generator reserve over peak per cent	30.8	32.0	36.1	42.0	34.2	53.8	37.7	60.5	46.5
Total effective reserve over peak, per cent	19.8	13.2	19.0	25.0	18.8	27.1	9.7	27.5	20.6
Average size of plant effective capacity kilowatts	650	1,510	3,320	7,000	14,500	28,000	55,500	131,000	15,300
Average size of unit do	273	540	905	1,580	3,000	6,420	12,600	15,800	4,140
Load factor per cent	21.3	24.5	27.3	24.7	28.5	32.4	38.8	37.3	34.2
Effective capacity factor, per cent	17.7	21.4	23.0	19.7	24.2	25.4	35.5	29.4	28.4
Fuel per kilowatt-year of effective capacity short tons	4.85	3.96	3.64	3.30	3.21	2.80	3.42	2.76	3.10
Coal per kilowatt-hour pounds	6.23	4.22	3.60	3.80	3.05	2.50	2.20	2.14	2.48
Cost of maintenance, labor, and supplies per kilowatt-year of effective capacity	$23.10	$18.10	$14.56	$12.21	$10.15	$6.82	$7.80	$5.46	$9.23

FUEL REQUIREMENTS.

Table 5 (p. 48) shows the quantities and cost of the coal used by electric utilities in the superpower zone in 1919 and the results in heat units. The total cost of this coal, delivered, was $63,227,812. The cost per short ton ranged from $2.79 at the Wilkes-Barre load center to $8.75 at the Lowell load center. The average cost for the zone was $5.35. The quantity of coal consumed ranged from 2.27 pounds per kilowatt-hour at the Providence load center to 6.23 pounds at the Utica load center. The Utica load center is, however, supplied largely by hydro-electric power; its steam-electric plants are small and are used principally as a reserve. The average quantity of coal consumed per kilowatt-hour in the superpower zone was 2.73 pounds, and the average heat utilization per kilowatt-hour was 35,800 British thermal units.

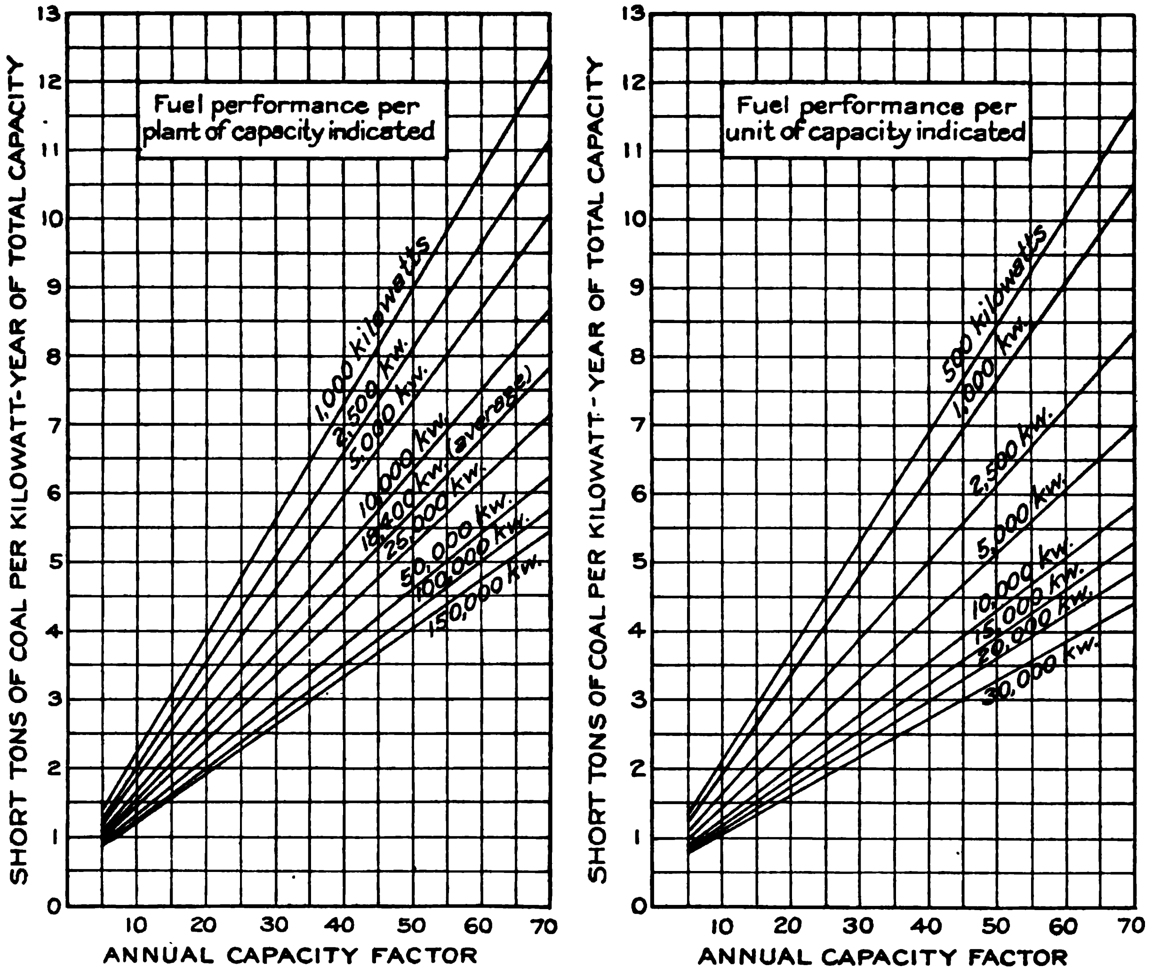


FIGURE 11.—Fuel performance in 1919 per plant and per unit of 196 electric-utility plants in the superpower zone that used bituminous coal.

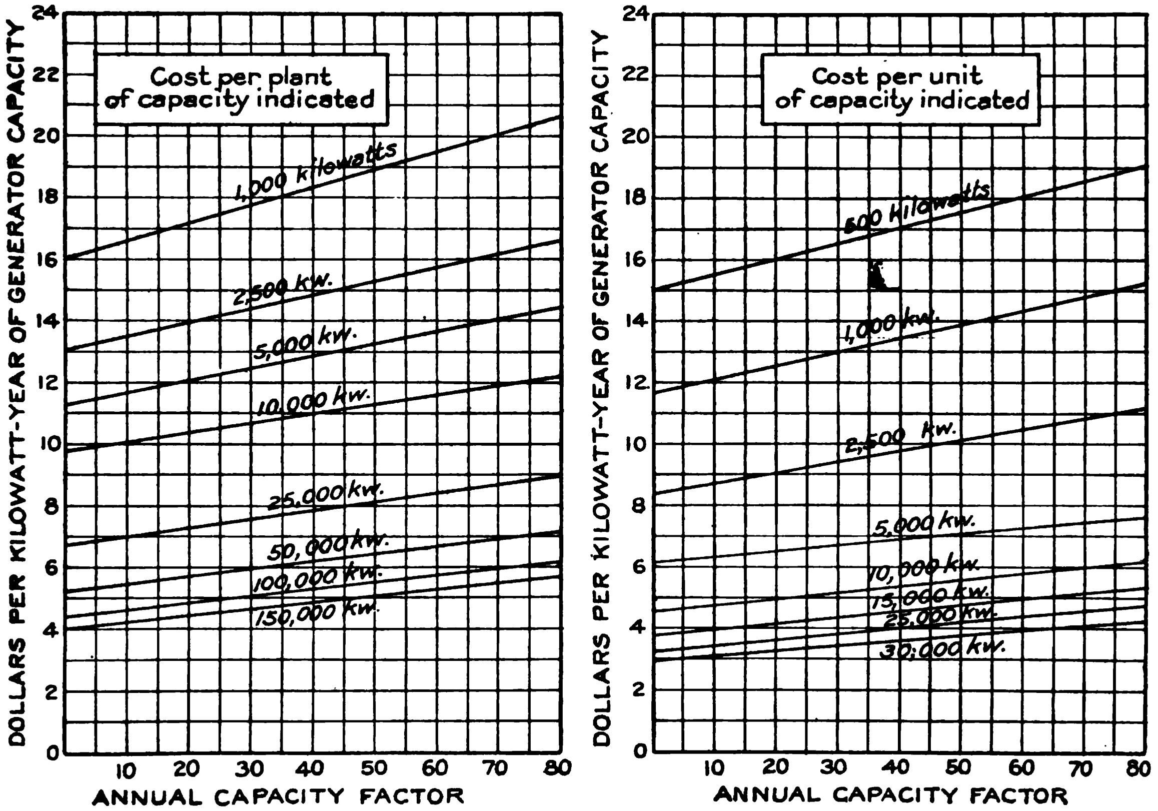


FIGURE 12.—All operating costs in 1919, except that of fuel, per plant and per unit for 196 electric-utility plants in the superpower zone that used bituminous coal.

TABLE 5.—*Fuel requirements and performance of electric utilities in the superpower zone in 1919.*

Geographic division and load center.	Coal used.					Heat value (thousands of British thermal units per kilowatt-hour).
				Cost.		
	Thousands of short tons.	Short tons per kilowatt-year of effective capacity.	Pounds per kilowatt-hour.	Per short ton.	Per year.	
Eastern New England:						
Boston	911.20	2.83	2.40	$6.50	$5,927,507.29	33.7
Lowell	179.11	2.38	2.49	8.75	1,568,282.26	33.3
Providence	506.06	2.66	2.27	7.70	3,891,543.19	31.5
Worcester	182.09	2.83	2.78	6.77	1,233,291.44	37.2
	1,778.46	2.73	2.40	7.10	12,620,624.18	33.4
Western New England:						
Hartford	158.33	2.96	2.75	6.63	1,049,624.24	37.6
New Haven	562.18	3.22	2.96	6.47	3,633,012.15	39.7
Northampton	184.77	2.03	2.99	6.73	1,241,529.15	40.7
	905.28	2.84	2.93	6.54	5,924,165.54	39.5
Mohawk:						
Utica	54.23	3.05	6.23	5.43	294,400.33	80.0
Schenectady	85.13	2.23	5.62	4.98	423,693.27	70.0
	139.36	2.50	5.85	5.15	718,093.60	73.7
Metropolitan:						
Newark	939.45	4.20	2.68	5.67	5,322,720.14	35.4
New York	3,800.01	3.40	2.42	5.61	21,322,522.19	32.2
	4,739.46	3.53	2.46	5.64	26,645,242.33	32.8
Hudson:						
Poughkeepsie	65.37	2.83	3.47	5.72	373,078.08	46.3
	65.37	2.83	3.47	5.72	373,078.08	46.3
Anthracite:						
Pottsville	99.73	7.55	4.73	3.32	331,463.33	55.4
Allentown	580.69	7.70	3.66	3.42	1,983,579.13	41.2
Wilkes-Barre	908.64	8.45	4.96	2.79	2,537,057.10	55.5
	1,589.06	8.10	4.38	3.05	4,852,099.56	49.2
Southern:						
Trenton	100.20	5.55	4.78	5.23	523,175.39	63.6
Harrisburg	331.79	5.08	3.78	3.28	1,088,894.93	41.7
Philadelphia	1,648.50	3.90	2.62	4.77	7,855,907.51	35.0
Baltimore	240.54	1.30	2.74	5.10	1,227,011.85	37.0
Washington	268.05	2.69	2.39	5.21	1,399,519.57	32.0
	2,589.08	3.28	2.74	4.67	12,094,509.25	36.1
Superpower zone	11,806.07	3.49	2.73	5.35	63,227,812.54	35.8

PRODUCTION COST.

Table 6 shows the production cost of the electric utilities in the superpower zone in 1919. The operating expense of the steam-electric plants was $91,195,000, of which 69 per cent was for coal and 31 per cent for maintenance, labor, and supplies. The total annual production cost of the steam plants was $183,441,333, of which the fixed charges were 44.5 per cent, the operating expense 49.7 per cent, and the general expense 5.8 per cent. The total annual production cost of the hydroelectric plants was $15,661,382, of which the fixed charges were 81 per cent, the operating expense 11.1 per cent, and the general expense 7.9 per cent. The average production cost by steam was $0.0212 per kilowatt-hour, and the average production cost by water was $0.0094 per kilowatt-hour.

TABLE 6.—*Annual production cost of electric utilities in the superpower zone, 1919.*

Geographic division.	Total annual operating expense.				Fixed charges.	
	Steam-electric plants.			Hydroelectric plants.	Steam-electric plants.	Hydroelectric plants.
	Fuel.	Maintenance, labor, and supplies.	Total.			
Eastern New England	$12, 620, 624	$5, 479, 617	$18, 100, 241	$388, 192	$18, 532, 300	$2, 394, 350
Western New England	5, 924, 166	2, 827, 322	8, 751, 488	438, 337	8, 263, 600	2, 476, 820
Mohawk	718, 094	613, 092	1, 331, 186	376, 327	1, 592, 600	3, 541, 200
Metropolitan	26, 645, 242	10, 913, 651	37, 558, 893	67, 330	29, 143, 100	369, 800
Hudson	373, 078	208, 774	581, 852	69, 904	706, 000	245, 630
Anthracite	4, 852, 100	2, 503, 538	7, 355, 638	63, 687	5, 167, 200	183, 510
Southern	12, 094, 509	5, 421, 743	17, 516, 252	340, 449	18, 269, 570	3, 474, 700
Superpower zone	63, 227, 313	27, 967, 737	91, 195, 550	1, 744, 226	81, 674, 370	12, 686, 010

Geographic division.	General expenses.		Total annual production cost.		Cost per kilowatt-hour.		Cost per kilowatt-year of effective capacity.	
	Steam-electric plants.	Hydroelectric plants.	Steam-electric plants.	Hydroelectric plants.	Steam-electric plants.	Hydro-electric plants.	Steam-electric plants.	Hydro-electric plants.
Eastern New England	$2, 456, 444	$222, 256	$39, 088, 985	$3, 004, 798	$0. 0264	$0. 0102	$60. 00	$31. 30
Western New England	1, 347, 010	377, 910	18, 362, 098	3, 293, 067	. 0297	. 0109	57. 50	29. 50
Mohawk	274, 370	339, 780	3, 198, 156	4, 257, 307	. 0670	. 0109	57. 25	36. 70
Metropolitan	3; 096, 990	40, 800	69, 798, 983	477, 930	. 0182	. 0194	52. 00	54. 90
Hudson	124, 280	19, 740	1, 412, 132	335, 274	. 0375	. 0147	61. 20	38. 60
Anthracite	953, 190	30, 560	13, 476, 028	277, 757	. 0186	. 0161	68. 80	54. 70
Southern	2, 319, 150	200, 106	38, 104, 972	4, 015, 249	. 0202	. 0066	48. 20	38. 10
Superpower zone	10, 571, 434	1, 231, 146	183, 441, 354	15, 661, 382	.02124	. 0094	54. 30	34. 70

REPRODUCTION COST.

Table 7 shows the cost of reproducing the electric-utility plants in the superpower zone as equipped in 1919. The total cost is $598,277,000, of which approximately 85.5 per cent is that of reproducing the steam-electric plants. The method used in arriving at these costs is stated in Appendixes F and G.

TABLE 7.—*Reproduction cost for electric public-utility power plants as of 1919.*

Geographic division.	Steam-electric plants.	Hydroelectric plants.	Total plants in superpower zone.	Percentage.	
				Steam-electric plants.	Hydro-electric plants.
Eastern New England	$115, 949, 000	$16, 501, 000	$132, 450, 000	87. 5	12. 5
Western New England	52, 165, 000	16, 713, 000	68, 878, 000	75. 8	24. 2
Mohawk	9, 957, 000	24, 442, 000	34, 399, 000	28. 9	71. 1
Metropolitan	181, 899, 000	2, 550, 000	184, 449, 000	98. 6	1. 4
Hudson	4, 407, 000	1, 693, 000	6, 100, 000	72. 2	27. 8
Anthracite	32, 296, 000	1, 265, 000	33, 561, 000	96. 2	3. 8
Southern	114, 477, 000	23, 963, 000	138, 440, 000	82. 7	17. 3
Superpower zone	511, 150, 000	87, 127, 000	598, 277, 000	85. 5	14. 5

APPENDIX C.

PROPOSED ELECTRIFICATION OF HEAVY-TRACTION RAILROADS IN THE SUPERPOWER ZONE.

By CARY T. HUTCHINSON, N. C. MCPHERSON, and others of engineering staff.

ADVANTAGES OF UNIFIED OPERATION.

Many of the railroad lines in the superpower zone have been built piecemeal to serve the interests of different communities as need arose, and consequently there has been considerable duplication of trackage and an unbalanced development. Consolidation subsequently improved the conditions, and the trackage now under steam operation in the zone is in general fully loaded.

Better results would be obtained, even under steam operation, by treating these systems as a unit. A substantial increase in traffic could be handled by better routing; by setting aside certain tracks for exclusive service where lines are parallel, as between Washington and Philadelphia or New York and Scranton; by eliminating competitive branch lines; and by abandoning branch lines that are unprofitable though not competitive. These improvements and many others have been discussed within the last few years, but no action has been taken.

Even after all possible improvements of this kind had been made, however, the railroad system would still be an inferior machine, with compromises in all its parts. The character and the cost of the service would not be essentially altered.

Unified operation by electricity, on the other hand, would give much better conditions than any that could possibly be attained under unified operation by steam. There would be a new motive power, in which all units or parts designed for similar service would be identical and interchangeable. There would be pooling of all power, with great reduction of reserves. Repair shops would be consolidated, and maintenance would become a standardized manufacturing job. Track capacity would be greatly increased, and certain tracks would be allocated to freight or passenger service exclusively. All freight trains would be run on schedule; the average speed would be more nearly the same and would be increased at least to the 12.5 miles an hour needed to avoid the present punitive overtime payments. Engine-house facilities would be much simplified by consolidation.

A specific illustration will show how wide the field is for possible savings under unified control. In 1919 one of the large railroads in the superpower zone spent about $20,000,000 for locomotive maintenance, and another spent about $40,000,000, the costs per locomotive-mile amounting, respectively, to 21 cents and 38 cents. Prorated to a weight of 100 tons on drivers, these costs become 24 cents and 46 cents, a difference of 90 per cent. The difference in average service is not sufficient to account for this difference in cost, which could not persist under unified control.

These improvements in operation can be made more readily under electric service than under steam, for a change in the power system would bring fresh minds into the service and would consequently liberate the mental operations of the average railroad man from their conventional routine. Under electric operation, for instance, the entire traffic between Philadelphia and Washington could readily be carried over the rails of the Pennsylvania system, those of the Baltimore & Ohio being left for future growth. Similarly, electric operation in the vicinity of Boston and New York would leave a margin of track capacity so great that no money need be spent for many years for further extensions of track. This release of trackage is one of the very notable advantages that would follow unified electric operation of the railroads in this territory. The great expense of any large increase in trackage should of itself force electrification; the total cost 20 years hence will be less if electrification is begun now than the cost of the added track and terminal facilities necessary under steam operation to provide for the inevitable 100 per cent increase in traffic within that time.

The reserves of men and of machinery required for joint operation will be much less than the aggregate of the separate reserves required for individual operation. The great waste involved in the maintenance of separate reserves of motive power is exhibited by the operating statistics of the roads, quoted elsewhere, which show that the average freight locomotive in this territory is in productive service only 3,250 hours out of the 8,760 hours in a year, and the average passenger locomotive only 2,630 hours. With joint electric operation and consequent unification of types of motive power there would be a striking improvement. The steam locomotive runs 8 hours a day; the electric locomotive 20 hours.

The fundamental reason for coordinated control of railroad operations is precisely the same as that for regional control of the generation of electric energy. The greatest economy can be attained only by intelligent unified direction of the movements of all parts of the system for the best interests of the whole.

SPECIFIC ADVANTAGES OF ELECTRIFICATION.

In addition to the general economic advantages that would be gained by joint operation of the rail systems within the superpower zone by either steam or electricity, there are other advantages inherent in operation by electricity. These may be classified as advantages of electric traction in operation and advantages of the electric locomotive as a machine.

ADVANTAGES IN OPERATION.

Some of the advantages of electric operation are the conservation of national resources, both of coal and labor; an increase in the capacity of main and yard tracks; an improvement of the physical condition of terminals and an increase in the value of the property, as shown by the New York Central and Pennsylvania terminals in New York City; benefits both to the traveling public and to residents along the route through the elimination of noise and smoke, the possibility of providing multiple-level terminals and freight warehouses; and economy in operation through the use of fuel and machinery for generating energy by a few skillful operators in economical stations as contrasted with a large number of technically ignorant operators with small, uneconomical machines.

The electric locomotive is equipped with meters that afford complete knowledge and control of operating conditions and that are also a valuable guide in handling the train, particularly in starting a long, heavy train. With electric traction the economy of the entire sequence of operation is not dependent upon one man, as it is with steam. Operation is therefore no longer a matter of individual human judgment, skill, or fidelity. It is this unfortunate human element that nullifies the theoretical advantages of the "full-jeweled movement" steam locomotive. The effectiveness of the devices for increasing efficiency and capacity, such as brick arches, superheaters, stokers, siphons, automatic fire doors, and power reverses, necessarily depends on the intelligence and faithfulness of the average engineer, and in consequence the average results are low. The inherent wastefulness of the steam locomotive is proved by its own advocates in their claim that "40 per cent of its coal can be saved by the careful use of these auxiliary devices." Then why be skeptical of a saving of 60 per cent by a modern power station, which has all these devices in greater completeness and, in addition, has brains to use them?

The speed of different classes of trains will be more nearly uniform. Much heavier trains can be handled, and at the same time light freight trains can be moved at the speed of local passenger trains. It has been proved that for the heaviest freight service, such as mountain-grade work, the electric locomotive is superior to the steam locomotive, but its superiority in handling light freight at high speed is not so generally understood.

As the electric locomotive is simple and as all locomotives of a given class are identical and no more skill is required to operate them than is demanded of an ordinary chauffeur, all locomotives will be pooled, so that the total number required will be materially reduced.

A considerable saving in time and hence an increase in capacity will be made by lengthening the operating divisions, which will be from 200 to 400 miles long instead of 100 miles. An electric passenger locomotive will run in the morning from New York to Boston and will return in the afternoon or at night, making a total run of 450 miles a day. A similar round trip will be made between New York and Washington, or New York and Syracuse. The electric locomotive can be kept at work on the road for 20 hours a day, and if operated at an average speed of 25 miles an hour can run 500 miles a day. This mileage, however, is double that of the electric passenger engines now used on the New Haven line and is higher than would be obtained as an average, but there is every reason to believe that with unified operation an average between 250 and 500 miles can be made.

The flexibility of the electric locomotive is much greater than that of the steam locomotive. Its capacity is determined by heating and therefore by the average work it has to do, and not by the maximum grade, which is taken care of by the overload capacity of the engine. With electric traction the maximum grade for the profiles within the superpower zone is practically eliminated as the determining factor in locomotive equipment.

The availability of the electric locomotive for service is at least twice as great as that of the steam locomotive. After a trip it can be thoroughly inspected in less than an hour, whereas the thorough inspection of a heavy steam locomotive consumes four to ten hours. It requires no water, fuel stations, ashpits, or turntables. The repair-shop capacity required is less than a third of that needed for steam locomotives. The expense of track maintenance is reduced, and the ballast is cleaner. The engine-house expense is reduced nearly to a negligible amount. In the electric locomotive energy can be regenerated where the profile permits it, thus saving some energy and much wear of brake shoes, bettering the handling of trains, and consequently saving expense in freight-car maintenance.

As a result of these and other advantages the electric locomotive should, under favorable conditions, handle twice as many ton-miles as the steam locomotive per locomotive-year; on the Norfolk & Western it actually handles three times as many ton-miles. This gain is not possible under all conditions, but it is possible where the traffic is great and the tracks, yards, and terminals are congested, as they are in the superpower zone.

Electric traction, then, gives increased capacity of main track, yard track, and locomotives with reduced cost of operation and maintenance per ton-mile and per passenger-mile.

ADVANTAGES OF THE ELECTRIC LOCOMOTIVE AS A MACHINE.

The electric locomotive is a better machine than the steam locomotive for the following among other reasons: It has no boilers or firebox; it has a shorter rigid wheel base; it carries no tender; it has a greater ratio of weight on drivers to total engine weight; it has less weight per driving axle, and a greater proportion of its weight is spring borne; it has uniform torque and therefore a higher coefficient of adhesion; it can be built for any power desired by increasing the number of driving axles and is therefore free from limitations of length; its maximum torque is available at much higher speed; the steam locomotive can work to an adhesion of 20 per cent up to only 10 or 12 miles an hour, whereas the electric locomotive can work to this adhesion up to 20 to 25 miles an hour; its efficiency over a range of load from 50 to 100 per cent varies only a few per cent and is constant throughout its life, whereas the efficiency of the steam locomotive varies over a wide range with age and use—a modern superheated steam locomotive requires 50 per cent more steam per horsepower-hour at full load than at half load; and finally, a steam locomotive must burn coal in descending a grade on which an electric locomotive will regenerate energy. To sum up, the electric locomotive is much the better transportation tool.

CLASSES OF ELECTRIC LOCOMOTIVES.

The great variety in types and weights of steam locomotives for freight, passenger, and switcher service is largely the result of growth, of change in fashion, and of whims of individual operating officers. There is no sound reason for such variety. The United States Railroad Administration formulated certain standard designs of steam locomotives, reducing the number of types to about ten, including the Mallet or articulated locomotive. With electric equipment this number can be reduced still further, certainly to as few as six types and possibly to three, as may be seen from an examination of the weight on drivers of the steam locomotives now in use. Those in freight service carry between 77 and 120 tons on drivers. Of those in passenger service, 80 per cent carry between 64 and 80 tons on drivers; but a few very small locomotives, probably 5 per cent of the total, are performing no material service. Of the switchers, 90 per cent carry from 65 to 85 tons on drivers, and a few carry more.

The entire freight service in the superpower zone can be handled by electric freight locomotives having two articulated 2-axle trucks, each carrying two motors geared to the axle, the mounting being essentially the same as that in a number of locomotives now in use and similar to the usual street-car mounting. There would be two classes of locomotives of this type—a light one carrying 80 tons on drivers and having a continuous drawbar pull of 22,000 pounds at 25 miles an hour, and a heavy one carrying 110 tons on drivers and having a continuous drawbar pull of 30,000 pounds at the same speed. These units can be combined in any reasonable number; the total load on drivers can be made equal to 80, 110, 160, 190, 220 tons or as much more as may be desired, being limited only by the strength of the draft rigging. A train can of course be double-headed, and a total tractive pull up to the maximum now in use can be obtained, with at least double the present speed.

For passenger service a similar arrangement would be used—that is, two articulated 2-axle trucks, with one motor geared to each axle. The motors may be practically the same as those in the freight locomotives, the only difference being a change in gear ratio. The passenger locomotive, however, would have leading and trailing trucks, with either two or four wheels, and the total weight would be redistributed. This passenger locomotive would be of two weights, the light one having 60 tons on drivers, and the heavy one 90 tons. These also may be combined, like the freight locomotives.

For the switchers one size will be adequate, with 70 to 75 tons on drivers, of the same type as the freight locomotive. Substantially the same frame and running gear can be used, with motors of less capacity.

All three types of locomotives will have the usual overload capacity, and all will be able to operate in starting and accelerating at 25 to 30 per cent adhesion.

These suggested sizes and types of locomotives can of course be varied greatly without sacrificing the advantage of unified electric operation, but identity of types for the same service throughout the superpower zone is essential.

SCOPE OF RAILROAD INVESTIGATION.

The general purpose of this investigation is to estimate the saving that would be effected by unified electric operation of the class 1 railroads within the superpower zone and to compare this estimated saving with the investment needed to effect it.

For this purpose the traffic conditions and the kind and quantity of service assumed are those of 1919, with the substitution of the electric for the steam locomotive. Of course, to insure the greatest gain from electric traction the entire transportation scheme must be revamped and fitted to the use of the new agent. An analysis based on such a change, however, would involve a detailed study of each road, and indeed of each division, which is not now possible.

The estimated saving in the cost of operation includes a reduction in certain items of steam-railroad cost that will be effected by the change of motive power. These items, named approximately in the order of their cost, are locomotive maintenance (including engine-house service), coal and water, and wages of crew. These items make up about 90 per cent of the expense affected by the change in the method of operation. In addition to the saving on these principal items there will be some saving—an amount hard to estimate—in the maintenance of curved track and freight cars, as a result of better train handling, and in certain minor items. The reduction in all these expenses will be offset by the cost of the electric energy required to do the work done by steam, the cost of the operation and maintenance of substations and of the electric overhead distribution system and track circuits, and the cost of maintenance of the electric locomotives.

The cost of electric energy, as the phrase is used here, means its total cost delivered to the railroad company's substation. The railroad company will have no investment in plant for generating or transmitting energy. Its investment begins with substations segregated for railroad use, owned by the railroad company individually or jointly with other companies.

This comparison of costs of investment and operation need take no account of the system of electric traction to be used except in so far as the use of different systems might entail different costs of operation or construction. The only two systems that are applicable to general traction within the superpower zone are the 3,000-volt direct-current system and the 11,000-volt (or higher) alternating-current system, both with overhead distribution circuits and rail return. Both of these systems are in successful use, and both can no doubt be designed and constructed to give satisfactory service in the zone.

The alternating-current system generally involves a lower investment cost than the direct-current system, as at low frequencies of supply substations with rotating machinery are replaced by transformers erected along the right of way; but this saving will not be effected under the super power system, for the frequency adopted for generation and transmission—60 cycles—requires substations with rotating machinery for the alternating-current as well as for the direct-current system, and the capital costs of the two are nearly equal.

The operation and maintenance of substations is ordinarily an additional burden in the direct-current system, but under the superpower system this would be offset by the addition of the frequency-changing equipment.

In order, then, to avoid some uncertain elements in the estimates of the cost of the alternating-current system it has been decided to base all estimates, both of operation and of construction, on the 3,000-volt direct-current overhead system. Substantially the same results in money could, however, be obtained with the alternating-current system, certain gains being offset by certain losses.

PROCEDURE FOLLOWED BY RAILWAY DIVISION.

The procedure of the railway division of the superpower survey in its study of the proposed electrification of the heavy-traction lines within the superpower zone comprised the collection of the physical data, the analysis of the data, and the formulation of conclusions.

DATA COLLECTED.

It was evident at the outset that it would not be adequate to study the roads as units but that a study should be made of the operating divisions of the railroads. A study of a railroad system as a whole, even if it lay entirely within the zone, would yield only average results, which might make a poor showing, whereas some of the divisions treated separately might make a good showing. It was therefore decided to ask each of the class 1 railroads within the superpower zone, of which a list is given below, to answer the questions on Form A, asking for certain fundamental data as to roadbed, equipment, and traffic. This information, like all other information sought, was to cover the year 1919.

Class 1 railroads within the superpower zone.

Boston & Maine.
Boston & Albany.
New York, New Haven & Hartford.
New York Central.
Delaware & Hudson.
Ulster & Delaware.
New York, Ontario & Western.
Lehigh & New England.
Lehigh & Hudson River.
Erie.
Delaware, Lackawanna & Western.
Lehigh Valley.
Central of New Jersey.
Long Island.
Pennsylvania.
Philadelphia & Reading.
Western Maryland.
Baltimore & Ohio.

Form A.

DATA SHEET FOR STEAM-OPERATED DIVISIONS.

BOUNDARY OF ZONE.

The zone included in the superpower survey is bounded as follows: Beginning where the 39° parallel crosses Delaware Bay, thence west to Washington, looping around Washington to include the city; thence north along the 77° meridian to its intersection with the 41° parallel; thence northeasterly to the intersection of the 43° parallel[1] and the 75° meridian; thence east to the vicinity of Portsmouth, N. H., looping around that city; and thence to the Atlantic seacoast, running outside of Long Island and New Jersey to the starting point on the 39° parallel.

The information requested herein refers to those parts of your system included within the above boundaries which are steam operated wholly or in part. (Data covering electric operations are outlined on "Data sheet for electric-operated divisions.")

ROADBED.

1. Outline map, showing all lines within the zone, indicating division points, number of main tracks, sidings, etc.; also indicate nearest division point outside of zone boundaries. Maps giving track profiles.
2. Diagram of principal yards, showing track layout.
3. Summation of mileage of track—e. g., first, second, and other main tracks; sidings, etc., for each division.

EQUIPMENT.

4. Number and classification of locomotives assigned to each division for freight, passenger, and switching service, giving for each class total weight with tender full and tender empty, and weight on drivers.

TRAFFIC.

Give separately for each division for each month of 1919, and total for the year:

5. Passenger service, train-miles, total locomotive-miles, and car-miles.
6. Freight service, train-miles and total locomotive-miles.
7. Gross ton-miles moved (including engine and tender), separately for freight and passenger.
8. Switching service, ton-miles, engine-miles, engine-hours, or in such other form as is at hand.
9. Amount of coal used for each class of service separately, if possible, and totals; kind of coal burned.
10. Average annual maintenance per locomotive-mile, separately for each class, if possible.

On January 15, 1921, all replies were in hand. A preliminary analysis was made of each set of replies when received; correspondence with the designated officer of each railroad helped to clear up points that were obscure and supplemented the information furnished; and all available data covering roadbed, equipment, and traffic were complete before the middle of February.

In addition to Form A a second sheet (Form B) was sent to the roads that were in part electrically equipped—the Baltimore & Ohio, the Pennsylvania, the Long Island, the New York Central, and the New York, New Haven & Hartford. The questions on this form are more general and were intended principally to elicit an accurate description of the physical property and equipment, together with sufficient statistics of traffic and of electric supply to permit their discriminating use in the allocation of energy required for the proposed unified operation of the steam roads. This information was all in hand at about the same time as the data from the steam roads.

Form B.

DATA SHEET FOR ELECTRIC-OPERATED DIVISIONS.

BOUNDARY OF ZONE.

The zone included in the superpower survey is bounded as follows: Beginning where the 39° parallel crosses Delaware Bay, thence west to Washington, looping around Washington to include the city; thence north along the 77° meridian to its intersection with the 41° parallel; thence northeasterly to the intersection of the 43° parallel and the 75° meridian; thence east to the vicinity of Portsmouth, N. H., looping around that city; and thence to the Atlantic seacoast, running outside of Long Island and New Jersey to the starting point on the 39° parallel.

The information requested herein refers to those parts of your system included within the above boundaries which are electrically operated wholly or in part. (Data covering all steam operations are outlined on "Data sheet for steam-operated divisions.")

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[1] The northern boundary of the zone as finally studied is the 44th parallel.

DESCRIPTION OF PHYSICAL PROPERTY.

1. A map showing the electric divisions, indicating tracks electrified and location of power house and substations, and track profiles.
2. A description of the system of generation, transmission, transformation, distribution, and utilization of the electric supply, including general equipment of power stations, substations, etc. Diagrams giving feeder, trolley (or third rail), and bonding layouts, and any printed descriptions or references thereto.
3. General description with drawings of locomotives in use, with total weight and weight on drivers.
4. Characteristic performance curves of locomotives—speed, torque, and heating.

TRAFFIC STATISTICS MONTHLY FOR 1919 AND TOTALS.

5. Train-miles (excluding multiple-unit cars) for freight and passenger, or for both.
6. Electric locomotive-miles for freight and passenger, or for both.
7. Multiple-unit car mileage and train mileage.
8. Statement of switching service in electric locomotive-miles, locomotive-hours, or in such form as is at hand.
9. Total gross ton-miles moved.

ELECTRIC SUPPLY.

10. Kilowatt-hours used—power-house output or substation input or output, preferably the latter. State point of measurement and whether record is available at either of the other points, even if for shorter periods.
11. Average daily, monthly, and annual load factors, stating how divisor is determined—that is, whether hourly peak or other.
12. Monthly peak, kilowatts.
13. Cost of electric supply in detail, if generated; or price, if purchased.
14. Cost of handling traffic per train-mile and per ton-mile.
15. Maintenance cost of locomotives per locomotive-mile and annual totals.
16. Cost of construction and equipment, subdivided into energy supply, transmission system, substations, distribution, and locomotives, with date of purchase.
17. Total cost of operation and maintenance of electric system under standard Interstate Commerce Commission classification.

Tables 8, 9, 10, and 11 set forth these fundamental data of the roadbed, equipment, and traffic of each of the steam roads within the zone, and Table 12 summarizes them for the entire zone. The Central New England is included with the New Haven road in all tables.

TABLE 8.—*Steam-operated tracks owned by class 1 railroads within superpower zone, 1919, in miles.*

System.	Main track.				Yards and sidings.	Total.
	First.	Second.	Other.	Total.		
Boston & Maine	1, 872	620	10	2, 502	1, 124	3, 626
Boston & Albany	393	220	110	723	419	1, 142
New York, New Haven & Hartford and Central New England [a]	2, 212	819	66	3, 097	1, 558	4, 655
New York Central [a]	790	594	414	1, 798	952	2, 750
Delaware & Hudson	377	233	56	666	337	1, 003
Ulster & Delaware	129			129	34	163
New York, Ontario & Western	180	154		334	118	452
Lehigh & New England	238	4		242	114	356
Lehigh & Hudson River	75			75	57	132
Erie	715	364	67	1, 146	725	1, 871
Delaware, Lackawanna & Western	590	357	122	1, 069	705	1, 774
Lehigh Valley	673	312	129	1, 114	774	1, 888
Central of New Jersey	638	252	80	970	822	1, 792
Long Island [a]	312	102	7	421	281	702
Pennsylvania [a]	2, 176	944	515	3, 635	2, 473	6, 108
Philadelphia & Reading	1, 581	627	157	2, 365	1, 375	3, 740
Western Maryland	95	20		115	58	173
Baltimore & Ohio	350	227	43	620	307	927
	13, 396	5, 849	1, 776	21, 021	12, 233	33, 254

[a] Electrified track omitted.

TABLE 9.—*Steam locomotives in service on class 1 railroads within superpower zone, 1919.*

System.	Freight.	Passenger.	Switching.	Total.
Boston & Maine	465	305	203	973
Boston & Albany	147	143	61	351
New York, New Haven & Hartford and Central New England	416	407	344	1, 167
New York Central	244	191	212	647
Delaware & Hudson	262	34	18	314
Ulster & Delaware	17	8	3	28
New York, Ontario & Western	77	39	8	124
Lehigh & New England	35	2	24	61
Lehigh & Hudson River	40	5	3	48
Erie	260	176	132	568
Delaware, Lackawanna & Western	312	128	130	570
Lehigh Valley	280	85	254	619
Central of New Jersey	253	155	177	585
Long Island	43	67	36	146
Pennsylvania	674	593	568	1, 835
Philadelphia & Reading	474	242	366	1, 082
Western Maryland	46	26	21	93
Baltimore & Ohio	106	63	141	310
	4, 151	2, 669	2, 701	9, 521
Per cent	43. 6	28. 0	28. 4	100

TABLE 10.—*Steam traffic movement on class 1 railroads within superpower zone, 1919.*

System.	Freight, trailing load (thousands of ton-miles).	Passenger (thousands of train-miles).	Switching (thousands of locomotive-miles).
Boston & Maine	6, 660, 000	9, 220	4, 460
Boston & Albany	3, 266, 000	3, 640	2, 330
New York, New Haven & Hartford and Central New England	8, 183, 000	11, 250	4, 900
New York Central	10, 914, 000	10, 400	5, 086
Delaware & Hudson	5, 650, 000	910	1, 143
Ulster & Delaware	85, 000	240	27
New York, Ontario & Western	915, 000	865	300
Lehigh & New England	488, 000	30	540
Lehigh & Hudson River	710, 000	125	80
Erie	5, 707, 000	4, 600	2, 306
Delaware, Lackawanna & Western	6, 200, 000	4, 100	3, 200
Lehigh Valley	5, 093, 000	2, 170	3, 480
Central of New Jersey	4, 400, 000	3, 810	3, 000
Long Island	299, 000	2, 500	1, 200
Pennsylvania	22, 545, 000	23, 426	14, 024
Philadelphia & Reading	10, 900, 000	7, 550	7, 763
Western Maryland	235, 000	240	120
Baltimore & Ohio	3, 379, 000	2, 950	2, 577
	95, 629, 000	88, 026	56, 536

TABLE 11.—*Coal used by steam locomotives of class 1 railroads within the superpower zone, 1919, in short tons.*

System.	Freight.	Passenger.	Switcher.	Total.
Boston & Maine	642, 500	485, 000	193, 500	1, 321, 000
Boston & Albany	397, 000	246, 000	83, 000	726, 000
New York, New Haven & Hartford and Central New England	800, 000	705, 000	279, 000	1, 784, 000
New York Central	724, 000	609, 500	272, 500	1, 606, 000
Delaware & Hudson	622, 000	62, 000	81, 000	765, 000
Ulster & Delaware	18, 700	14, 000	1, 300	34, 000
New York, Ontario & Western	108, 300	35, 000	16, 000	159, 300
Lehigh & New England	63, 100	2, 800	27, 500	93, 400
Lehigh & Hudson River	58, 000	7, 600	5, 300	70, 900
Erie	575, 500	356, 900	161, 000	1, 093, 400
Delaware, Lackawanna & Western	900, 000	300, 000	200, 000	1, 400, 000
Lehigh Valley	676, 000	187, 000	240, 000	1, 103, 000
Central of New Jersey	505, 700	260, 400	195, 400	961, 500
Long Island	84, 200	141, 200	48, 100	273, 500
Pennsylvania	1, 731, 200	1, 413, 000	750, 800	3, 895, 000
Philadelphia & Reading	1, 505, 100	495, 100	404, 500	2, 404, 700
Western Maryland	48, 000	16, 700	9, 600	74, 300
Baltimore & Ohio	312, 500	187, 800	140, 000	640, 300
	9, 771, 800	5, 525, 000	3, 108, 500	18, 405, 300
Per cent	53. 1	30. 0	16. 9	100. 0

TABLE 12.—*Summary of principal data for class 1 railroads within the superpower zone for 1919.*

Road	miles	13, 396
Main track	do	21, 021
Yards and sidings	do	12, 233
All tracks	do	33, 254
Freight locomotives		4, 151
Passenger locomotives		2, 669
Switcher locomotives		2, 701
All locomotives		9, 521
Freight trailing load	thousands of ton-miles	95, 629, 000
Passenger service	train-miles	88, 026, 000
Switcher service	locomotive-miles	56, 536, 000
Coal burned:		
Freight service	short tons	9, 771, 800
Passenger service	do	5, 525, 000
Switcher service	do	3, 108, 500
All services	do	18, 405, 300

In addition to the data from the railroads two large electric companies, the General Electric and the Westinghouse, were asked to prepare estimates of cost of substation equipment, of electric locomotives, of catenary construction, and of other electric facilities—all as of the year 1919. Similar data were also asked of the Ohio Brass Co. and one or two other companies. All made prompt and full response. After a provisional analysis of certain of these data the opinions of engineers of electric railways were sought, and their criticisms were considered in making up final estimates of cost of construction and of operation.

The locomotive-mile and the ton-mile were selected as bases for the electric comparisons, principally for the reason that locomotive maintenance is always reported "per locomotive-mile," both for steam and electric locomotives. The statistics of electric service for energy used can easily be put into any units. Form C was standardized, and the replies from the operating roads were all tabulated in this form, as shown on the following page.

Form C.

Comparison of steam and electric operation, M. & N. system, R. division.

	Freight.		Passenger.		Switcher.		All services.	
	Unit value.	Total.	Unit value.	Total.	Unit value.	Total.	Unit value.	Total.
1. Miles of road operated		293		293				293
2. Miles of track operated		505		505		221		726
Steam.								
3. Average number of assigned locomotives		96		89		60		245
4. Weight on drivers.tons	100	9,600	64	5,700	81	4,860	82.3	20,160
5. Locomotive-miles, thousands		1,728		4,150		1,654		7,532
6. Trailing ton-miles.do		2,433,000						
7. Car-miles.do				28,130				
8. Coal burned.tons		221,000		225,000		68,500		514,500
9. Coal per locomotive-mile.pounds		225		108		83		137
Electric.								
10. Kilowatt-hours (M-ton-mile basis).thousands	30	73,000						
11. Kilowatt-hours (locomotive-mile basis, thousands	42.3	73,000	20	83,000	15	24,800	24	180,800
12. Equivalent coal...tons		73,000		83,000		24,800		180,800
13. Coal saved, per cent and tons	67	148,000	63	142,000	64	43,700	65	333,700
Unit and total cost.								
14. Cost of coal and water[a]	$5.00	$1,105,000		$1,125,000		$342,500		$2,572,500
15. Cost of electric energy	.01	730,000		830,000		248,000		1,808,000
16. Excess cost of steam		375,000		295,000		94,500		764,500
17. Locomotive maintenance, steam[b]	.63	1,087,000	$0.366	1,519,000	$0.366	605,000	$0.426	3,211,000
18. Locomotive maintenance, electric[b]	.0823	142,200	.0823	341,500	.0823	136,100	.0823	619,800
19a. Maintenance of distribution system	600.00	84,000		218,000	400.00	300,000		602,000
19b. Substation operation and maintenance	.0007	51,000	.0007	58,100	.0007	17,400	.0007	126,600
20. Total cost, steam operation		2,192,000		2,644,000		947,500		5,783,500
21. Total cost, electric operation		1,007,300		1,447,600		701,500		3,156,400
22. Excess cost, steam operation	2,346	1,184,700	2,369	1,196,400	1,113	246,000	3,619	2,627,100

[a] Includes cost of fuel and water stations.

[b] Includes engine-house expense.

ANALYSIS OF DATA.

The first nine items of Form C are taken from the replies of the railroads to the questions of Form A. Items 10 and 11 cover the kilowatt-hours used.

The view here taken is that the steam locomotive is a machine doing useful work, which in freight service is represented by the gross weight of cars and contents multiplied by the distance moved—that is, the "trailing ton-miles." In this service variations in speed are of little consequence. The total tonnage movement is here referred to as "total ton-miles" or as "trailing ton-miles plus locomotive ton-miles."

The same procedure is followed in estimating the electric requirements—the electric locomotive is regarded as a machine substituted for the steam locomotive to do the same work. This procedure, however, does not lead to a direct statement of the saving in tonnage movement due to the smaller total weight of the electric locomotive as compared with that of the steam locomotive and tender. This difference, including for freight service the weight of the loaded tender and the part of the weight of the steam locomotive that is not on drivers, can be estimated separately; it is approximately 8 to 13 per cent of the trailing ton-miles. This difference is considerable, but it is not of so great consequence as is sometimes assumed.

In passenger service the work done is that of moving the loaded cars over a certain distance at a certain speed, and in this service the speed—the time consumed—is important.

ENERGY REQUIRED FOR ELECTRIC TRACTION.

The electric energy required for the railroads is determined from the records of lines already electrified, with proper allowance for variations in the conditions of operation, and from calculations based on the profile and the alinement of the roads considered and the efficiency of their locomotive and distribution systems.

The most extensive data available for lines already electrified are those of the New Haven road, which has installed wattmeters on its locomotives, keeps records of their individual performance, and classifies these records for the several kinds of service performed. This company also keeps daily records of the energy generated at its Coscob station and of that which it buys from the United Electric Light & Power Co. and the New York Central Railroad Co. Tables have been prepared by the New Haven company showing the energy used in slow-freight, local-freight, fast-freight, passenger, and multiple-unit service.

Table 13 is a summary of the average operating results of the New Haven system for 1919, showing the input to the locomotive in kilowatt-hours per locomotive-mile, train-mile, trailing ton-mile, total ton-mile (including locomotive), and car-mile for fast, slow, local, and all freight service; for express, local, and all passenger service; and for multiple-unit service. These figures can be used with confidence for railroads operating under conditions similar to those of the New Haven, which do not differ materially from those of a number of the other roads in the superpower zone, particularly along the coast. In fixing the units of energy for the different operating divisions much weight is given to the results of the New Haven service, modified as required by the profile and alinement under examination.

TABLE 13.—*Electric energy used by New Haven locomotives in 1919, in kilowatt-hours of locomotive input.*

	Per locomotive-mile.	Per train-mile.	Per 1,000 ton-miles.		Per car-mile.
			Trailing.	Train.	
Freight service:					
Fast	26.0	27.0	24.5	22.2	0.88
Slow	34.0	42.7	24.9	23.1	.93
Local	36.1	36.5	42.5	38.2	1.52
Average	33.6	40.0	26.6	24.5	.98
Passenger service:					
Express	13.7	24.6	44.3	32.6	2.96
Local	17.5	26.1	76.5	51.4	3.93
Average	14.7	25.1	51.4	37.0	3.21
Multiple-unit service		17.4	62.2	62.2	4.2
Yard switching	12.4				

Other records of electric energy for locomotive-drawn trains, both freight and passenger, are given in Table 14. The figures for the New Haven system in this table are referred to the substation output, an efficiency of 90 per cent being used for the distribution system. Those for the Chicago, Milwaukee & St. Paul are given on the authority of the electrical engineer of that road for the energy delivered to the substation, multiplied by 83 per cent as average substation efficiency; those for the New York Central Railroad were presented by the chief engineer of electric traction at the joint meeting of the American Institute of Electrical Engineers and the American Association of Mechanical Engineers October 22, 1920; those for the Pennsylvania Terminal are given in reports made to the superpower survey. All are reduced in Table 14 to the same point of reference—the substation output.

TABLE 14.—*Electric energy used for locomotive-drawn freight and passenger trains, in kilowatt-hours of substation output.*

	New Haven.[a]	Chicago, Milwaukee & St. Paul.[b]	New York Central.	Pennsylvania Terminal.
Freight service:				
Per train-mile	44			
Per locomotive-mile	37			
Per thousand ton-miles (trailing)	29	33		
Per thousand ton-miles (total)	27	29		
Passenger service:				
Per train-mile	28		30	
Per locomotive-mile	16			32
Per thousand ton-miles (trailing)	57	47	[c] 40 [d] 26	55
Per thousand ton-miles (total)	41	33		

[a] Energy at locomotive 1.17. [b] Substation input 0.83. [c] Average. [d] Minimum.

The second method of determining electric energy required consists in calculating, from profile and alinement, the work due to normal train resistance and adding to this the net work done against gravity, plus the work due to curvature, plus the work due to acceleration. For example, on the profile shown in figure 13, for eastbound movement it is assumed that no power is required to descend the 0.6 per cent grade, but no credit is taken for use of the kinetic energy accumulated at the bottom of this grade in ascending the next grade; for westbound movement it is assumed that no power is required on the 0.3 per cent grade for freight service, but that the difference between 0.3 and 0.5 per cent is used for passenger service. The lifting work is taken as the sum of the separate lifts; the work against curvature is the sum of the products of degrees of curvature taken from the alinement charts, multiplied by length of curve, and the unit resistance is taken at 0.8 pound per ton per degree. In freight service an acceleration from rest to 25 miles an hour and another from 10 to 25 miles an hour is assumed for each 10 miles. The sum of these elements gives the total work required at the rail to move a ton over the division considered. This process is carried through for movement in both directions, and the average of the two results is taken for the work required. This average divided by the efficiency from rail to substation input gives the watt-hours per ton-mile measured at the substation. For divisions on which the traffic is greatly unbalanced separate estimates were made for the eastbound and westbound movements.

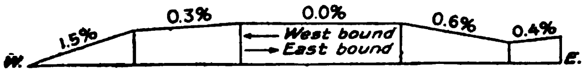

FIGURE 13.—Typical railroad profile.

Calculations made for a number of the operating divisions within the zone that differ most widely in grade and alinement show that the added resistance in freight service due to grade, curvature, and acceleration ranges from 0.5 to 10 pounds per ton. The maximum figure is that for the Jefferson division of the Erie, which includes a straight climb over a divide in both directions.

SWITCHER SERVICE.

The data of coal burned or energy required in switcher service are meager, consisting mainly of the results of a few tests recently made by the General Electric Co., of tests made by the Chicago Smoke Abatement Commission, and of tests made on the New Haven road. These tests show conclusively that the waste of coal in switcher service is great and that the actual work done by a switcher locomotive is small.

The tests in Chicago were made at a number of busy yards, in heavy service, chosen as typical of the conditions there. The average results are as follows:

Work done per locomotive-hour:		
Trailing	ton-miles	1,000
Total	do.	1,400
Coal used per locomotive-hour	pounds	824
Mileage per locomotive-hour		3.26
Trailing load	tons	306
Coal per trailing ton-mile	pounds	0.824
Coal per locomotive-mile, actual	do.	255
Coal per locomotive-mile, 6-mile basis[1]	do.	138
Time in motion, per movement	seconds	80
Time of stop, per movement	do.	53
Total time, per movement	do.	133
Length of run, per movement	feet	640

From these data the following deductions are made:

Average speed when moving	miles per hour	5.45
Maximum speed (say)	do.	10
Energy required at rail for acceleration per movement	watt-hours per ton	2.5
	watt-hours per ton-mile	21
Energy required at rail for train resistance	do.	16
Total energy at rail	do.	37
Total energy per locomotive-hour	kilowatt-hours	52
Coal burned per kilowatt-hour of work at rail	pounds	16
Efficiency assumed, rail to substation	per cent	63
Energy required for substation input, per locomotive-hour	kilowatt-hours	83

The tests made at Erie by the General Electric Co. with a storage-battery locomotive weighing 43 tons on drivers gave an average of 50 watt-hours per ton-mile of total train weight (including locomotive); the range from the six days' tests was from 47.8 to 55.7 watt-hours. Similar tests with a steam switcher weighing 40 tons on drivers gave 1.47 pounds of coal per total ton-mile. That is, in similar service the coal equivalent of 1 kilowatt-hour input to motors was 29 pounds, and that of 1 kilowatt-hour at rails was 34 pounds. The corresponding figure for road service, given below, is 7.5 pounds. Switcher service involves a great waste of coal due to large stand-by losses.

This 50 watt-hours per ton-mile is measured on the locomotive; referred to substation input it becomes 65 watt-hours per total ton-mile and 87 watt-hours per trailing ton-mile where 25 per cent of the total train weight is in the locomotive. This is practically the same as the 83 watt-hours per trailing ton-mile (83 kilowatt-hours per locomotive-hour) deduced above from the Chicago tests.

The above figures are all in general accord with such data as have been published; some results, however, have indicated much lower figures—as low as 30 to 50 kilowatt-hours at the substation per locomotive-hour.

COAL SAVED.

The quantity of coal burned in a steam locomotive equivalent in work done to 1 kilowatt-hour delivered to an electric locomotive is estimated by the electrical engineer of the Baltimore & Ohio Railroad at 7.5 pounds and by the electrical engineer of the Chicago, Milwaukee & St. Paul Railway at 8.4 pounds. A committee of the American Electrical Railway Association has published data for a modern Mallet locomotive, with superheater, which makes the equivalent coal per kilowatt-hour with stand-by losses 7.5 pounds. The same authority elsewhere gives 6.5 pounds as the equivalent of 1 kilowatt-hour at the power station, equal to 8.1 pounds per kilowatt-hour at the locomotive. Other electrical authorities give materially larger figures—some as much as 12 pounds. The weight of expert opinion is, then, that not less than 7.5 pounds of coal is required to do the work of 1 kilowatt-hour at the locomotive.

The approximate uniformity shown on the operating sheets (Form C) in the percentages of coal saved in the three services on the several roads by electric operation tends to confirm the validity of the figures taken for kilowatt-hours used (items 10 and 11, Form C); on the

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A standard method of expressing switching units is at 6 miles per locomotive-hour.

assumption that all the roads in the territory are fairly well operated there should be approximately the same percentage of saving of coal on each road in freight, passenger, and switcher service, respectively. The performance of individual steam locomotives of course differs materially, but that of groups only slightly. The operating sheets show that the coal saved in freight service is from 50 to 70 per cent. For passenger service the saving is from 65 to 75 per cent, in general somewhat higher than for freight service, as would be expected, inasmuch as the freight locomotives are more closely proportioned to their work than passenger locomotives. Similarly the saving in switcher service is from 70 to 85 per cent, and this also is consistent, inasmuch as the switchers operate under the worst conditions.

EFFICIENCY.

The power and the losses in the several parts of the direct-current system from substation input to rail for average load are taken as—

	Per cent.
Substation input	100
Substation output	85
Distribution efficiency	90
Input to locomotive	76.5
Efficiency of locomotive	82.5
Output of locomotive	63

Under these conditions a freight train with a resistance of 6 pounds per ton would require 19 watt-hours per ton-mile, and a passenger train at 10 pounds per ton would require 32 watt-hours per ton-mile.

EQUIVALENT COAL.

Item 12 on Form C, "equivalent coal," is uniformly taken at 2 pounds per kilowatt-hour for energy delivered at the substation. All losses of energy in transmission and conversion from the power station to the substation are included in this figure. If 1.5 pounds per kilowatt-hour is the average for coal used in superpower stations, then the assumption of 2 pounds per kilowatt-hour at the substation means an efficiency of only 75 per cent from substation input to power house. This is low—80 to 85 per cent is more nearly correct. The "equivalent" coal is given only to show the percentage of coal that would be saved under electric operation; it does not enter into the comparative costs.

COST OF COAL.

Item 14 covers the total estimated cost of coal at the railroad's fuel stations, including freight on home lines, plus the estimated cost of operating and maintaining the fuel and water stations, prorated per ton to the total coal used.

Only one or two of the replies from the railroads included freight on home lines. In this analysis the cost of delivering coal to points in the superpower zone has been determined from a base mine cost of $2.90 a ton for 1919. The cost of the coal delivered as thus determined is substantially the same as the cost reported by the railroad companies, after allowance for freight on home lines. In order to make the costs justly comparable throughout a unit price was adopted for railroad coal for each section; the cost per ton as thus fixed for the several sections of the zone is $5, $5.50, and $6 for the south, central, and north sections, respectively. These costs include the prorated cost of fuel and water stations. The uniform base mine price used affords a truer comparison of steam and electric operation than the variable figures of the railroad companies.

COST OF ELECTRIC ENERGY.

It is assumed that the railroads will purchase energy delivered at high pressure at substations on or near the railroad right of way, at the flat rate of 1 cent per kilowatt-hour. This price includes the total cost of generating and transforming electric energy and transmitting it to the railroad substations, with profit to the supplier.

No estimate is made of the maximum power required for the service, except in so far as it is involved in the determination of the substation capacity and the feeder capacity, for as the cost of energy is figured at a flat rate per kilowatt-hour the maxima to be provided do not enter into this item.

Similarly, no definite ratio has been assigned to the eastbound and westbound traffic; in general this ratio is similar for most of the roads in the zone. Where the profiles indicate that greater work is required in one direction than in the other this difference has been taken into consideration in the allocation of energy. All estimated figures here given are assumed averages and would of course have to be modified for each division by detailed study.

The load factor of the several divisions will be between 40 and 60 per cent, and 50 to 53 per cent may be taken as the average for unified operation.

MAINTENANCE OF STEAM LOCOMOTIVES.

Item 17 of Form C is the cost of steam-locomotive maintenance as reported by the railroads, plus engine-house expense, prorated to the locomotive-mile. This item is the one affected most by electrification. The saving in maintenance by the electric locomotive is from two to five times the saving in coal; and this difference accounts for 50 to 100 per cent of the net saving made by electric traction.

Table 15 gives the cost of steam-locomotive maintenance for the principal systems in the superpower zone for 1919; the amounts included are Interstate Commerce Commission accounts No. 308, locomotive repairs, and Nos. 388 and 400, engine-house expenses for yard and train locomotives. These costs are reduced to the cost per locomotive-mile by taking as divisor the total mileage. From this result and the average weight of locomotive on drivers the sum of the cost of repairs and engine-house expense is prorated to the cost per locomotive-mile for 100 tons on drivers.

TABLE 15.—*Cost of maintenance of steam locomotives for 1919.*

System	Average weight on drivers (tons).	Distance traveled (thousands of locomotive-miles).	Interstate Commerce Commission accounts.							
			Repairs (No. 308).		Engine-house expense (Nos. 388 and 400).		Total cost.			
							Actual.		Prorated to 100 tons on drivers.	
			Per locomotive-mile (cents).	Per locomotive-year.	Per locomotive-mile (cents).	Per locomotive-year.	Per locomotive-mile (cents).	Per locomotive-year.	Per locomotive-mile (cents).	Per locomotive-year.
Boston & Maine	80.9	24,592	25.33	$5,562	8.66	$1,904	33.99	$7,466	55.63	$12,263
New York, New Haven & Hartford	63.9	23,071	29.9	6,110	11.02	2,253	40.92	8,363	64.05	13,210
Central New England	68.6	1,844	31.23	7,578	10.37	2,540	41.60	10,118	60.65	14,755
New York Central	86.5	91,313	21.15	5,203	8.55	2,103	29.70	7,306	34.28	8,433
Delaware & Hudson	89.2	11,015	32.6	7,319	12.22	1,832	44.82	9,151	50.20	10,269
Lehigh & New England	74.2	1,212	27.8	5,521	7.82	1,554	35.62	7,075	48.05	9,545
Lehigh & Hudson River	76.3	767	27.8	4,267	8.77	1,345	36.57	5,612	47.94	7,362
Erie	90.4	26,078	45.6	9,790	9.65	2,070	55.25	11,860	61.19	13,126
Delaware, Lackawanna & Western	77.9	19,263	26.9	6,836	9.45	2,401	46.35	9,237	46.62	11,855
Lehigh Valley	85.6	17,883	40.6	7,126	8.75	1,537	99.35	8,663	57.62	10,115
Central of New Jersey	72.9	12,289	29.2	6,210	6.24	1,328	41.60	7,538	48.55	10,339
Pennsylvania	83.53	112,595	38.6	9,216	6.85	1,634	45.45	10,850	54.60	12,983
Philadelphia & Reading	78.3	22,164	32.6	6,853	8.93	1,879	31.53	8,732	53.00	11,152
	80.76	364,086	31.8	7,246	8.39	1,911	40.19	9,157	49.80	11,310

Table 16 gives similar data for the New York Central, Pennsylvania, Reading, New Haven, and Erie systems for 1911 to 1919. The weighted average is given for the years 1911 to 1915, inclusive, a period during which there was practically no variation in these unit costs.

It is difficult to find a satisfactory explanation of the great variations in these figures among the different systems; the division of total cost between repairs and engine-house expense differs somewhat, certain roads throwing more of the work on the engine house; but the sum of the two items is still widely divergent. There is no difference in the kind of service to which the locomotives are put that will account for these marked variations.

TABLE 16.—*Cost of maintenance of steam locomotives for 1911–1919.*

System.	Average weight on drivers (tons).	Distance traveled (thousands of locomotive-miles).	Interstate Commerce Commission accounts.							
			Repairs (No. 308).		Engine-house expense (Nos. 388 and 400).		Total cost.			
							Actual.		Prorated to 100 tons on drivers.	
			Per locomotive-mile (cents).	Per locomotive-year.	Per locomotive-mile (cents).	Per locomotive-year.	Per locomotive-mile (cents).	Per locomotive-year.	Per locomotive-mile (cents).	Per locomotive-year.
New York Central:										
1911–1915	75.36	66,356	9.04	$2,460	3.1	$849	12.14	$3,309	16.11	$4,391
1916	82.24	108,626	7.6	2,421	3.06	972	10.66	3,393	12.96	4,126
1917	83.60	106,403	10.0	3,051	4.07	1,241	14.07	4,292	16.83	5,134
1918	85.60	100,576	17.59	4,689	7.30	1,947	24.89	6,636	29.08	7,752
1919	86.50	91,313	21.15	5,195	8.54	2,100	29.69	7,295	34.32	8,434
Pennsylvania:										
1911–1915	75.85	94,142	12.7	3,221	2.8	710	15.50	3,931	20.44	5,183
1916	83.4	105,522	13.1	3,478	2.6	687	15.70	4,165	18.82	4,994
1917	87.6	108,638	17.5	4,620	3.4	899	20.90	5,519	23.86	6,300
1918	90.4	122,965	32.88	8,960	3.7	1,784	36.58	10,744	40.46	11,885
1919	91.0	112,595	38.62	9,175	6.8	1,627	45.42	10,802	49.91	11,870
Philadelphia & Reading:										
1911–1915	62.92	24,631	11.69	2,886	3.04	750	14.73	3,636	23.41	5,779
1916	70.83	27,422	12.28	3,397	3.19	883	15.47	4,280	21.84	6,043
1917	73.20	28,126	17.85	4,993	4.14	1,156	21.99	6,149	30.04	8,400
1918	75.4	27,080	28.17	7,423	7.50	1,975	35.67	9,398	47.31	12,464
1919	78.3	22,164	32.6	6,853	8.93	1,879	41.53	8,732	53.04	11,152
New York, New Haven & Hartford:										
1911–1915	50.7	27,027	9.6	2,171	3.00	681	12.60	2,853	24.85	5,625
1916	55.6	27,495	9.98	2,272	3.61	822	13.59	3,094	24.44	5,565
1917	57.5	26,099	14.0	3,160	4.77	1,078	18.77	4,238	32.64	7,370
1918	61.4	24,784	30.85	6,400	8.99	1,861	39.84	8,261	64.88	13,454
1919	63.9	23,071	29.9	6,110	11.04	2,253	40.94	8,363	64.07	13,088
Erie:										
1911–1915	74.1	28,768	11.21	2,430	3.45	749	14.66	3,179	19.78	4,290
1916	82.3	31,621	15.65	3,765	3.90	936	19.55	4,701	23.75	5,712
1917	87.6	29,903	24.20	5,400	6.11	1,360	30.31	6,760	34.60	7,717
1918	90.0	29,316	45.3	9,950	11.75	2,582	57.05	12,532	63.39	13,924
1919	90.2	26,078	45.6	9,790	9.65	2,070	55.25	11,860	61.25	3,1481

MAINTENANCE OF ELECTRIC LOCOMOTIVES.

Item 18 of Form C, cost of maintenance of direct-current locomotives, is taken uniformly at 10 cents per locomotive-mile per 100 tons on drivers. Actual costs are shown in Table 17 for all direct-current railroads in the United States for 1919, and in Table 18 for all grouped, with the weighted average, for 1913–1919. The base cost, as stated above, is applied for each road to the same average weight on drivers as that of the steam locomotives of the road.

TABLE 17.—*Cost of maintenance of direct-current electric locomotives, 1919.*

System.	Number of locomotives.	Average weight on drivers (tons).	Distance traveled (locomotive-miles).	Cost.				
				Actual.			Prorated to 100 tons on drivers.	
				Total.	Per locomotive-mile (cents).	Per locomotive-year.	Per locomotive-mile (cents).	Per locomotive-year.
Baltimore & Ohio	8	88	214,400	$24,600	11.47	$3.076	13.02	$3,491
Butte, Anaconda & Pacific	28	81	565,600	36,700	6.49	1,312	8.01	1,619
Chicago, Milwaukee & St. Paul	46	225	2,181,200	340,200	15.59	7,394	6.93	3,286
Michigan Central	10	108	245,500	34,600	14.10	3,462	13.05	3,205
New York Central	73	92	1,940,900	124,400	6.41	1,704	7.00	1,862
Pennsylvania Terminal	31	103	1,348,000	225,300	16.71	7,266	16.30	7,088
	196	124	6,495,600	785,800	12.10	4,009	9.77	3,238

TABLE 18.—*Cost of maintenance of direct-current electric locomotives, 1913–1919.*

Year.	Total distance traveled (locomotive-miles).	Cost per locomotive-mile per 100 tons on drivers (cents).
1913	2,422,800	5.83
1914	3,678,200	5.42
1915	3,808,800	5.44
1916	5,662,600	4.50
1917	6.797,000	5.89
1918	6,431,600	7.66
1919	6,495,700	9.77

DISTRIBUTION SYSTEM.

Item 19, Form C, maintenance of the electric distribution system, is taken at $600 per mile for main track and $400 per mile for yard track. These figures are based on the operating costs of certain electric roads and on a consideration of the usual maintenance costs of works of similar construction. Although $600 per mile of main track may seem low, it is probably not low if applied to a widespread system under unified control of both inspection and maintenance.

MAINTENANCE OF SUBSTATIONS.

Item 19b, Form C, cost of operation and maintenance of substations, is based on $1.50 per kilowatt per year of capacity, giving 0.7 mill per kilowatt-hour for a capacity factor of 25 per cent. This is adequate for stations of the size required in a unified system for the entire zone.

SAVING IN WAGES OF TRAIN CREWS.

Item 22 gives the excess cost for steam service as compared with electric service without allowance for saving in crew wages. Few data are available to show the amount of such saving, but those that are available indicate that it will be considerable. In the Butte, Anaconda & Pacific freight service there has been a decrease in crew time of 29 per cent per ton-mile and a simultaneous increase in tonnage moved of 35 per cent, together equivalent to a decrease of 47 per cent in crew wages. On the Chicago, Milwaukee & St. Paul there has been an average decrease of 25 per cent in crew time and an increase of 30 per cent in tonnage moved, together equivalent to a decrease of 42 per cent in crew wages. On the Norfolk & Western two electric locomotives pull the same train as three Mallets at double the speed, making an output per locomotive-hour three times as great and a consequent saving in crew wages of 67 per cent. The reason for this reduction in crew wages per ton-mile is clear: if a steam locomotive pulls a train 100 miles in 10 hours and an electric locomotive pulls it 100 miles in 8 hours, the use of the electric locomotive will save 33 per cent in crew wages (as 2 hours of the 10 would be paid for at double-time rates); and if the train pulled by the electric locomotive is 25 per cent heavier, the saving in wages will be 46 per cent. Such a saving is easily made.

It is not yet possible to determine exactly the manner in which traffic within the superpower zone will be handled, but it is conservatively assumed that there will be an increase in ton-miles per electric locomotive-hour of 33 per cent and a consequent reduction in crew wages per ton-mile of 25 per cent.

Table 19 shows for 1919 the crew wages in freight service per thousand ton-miles for the principal systems in the zone, the tonnage moved, and the saving due to an increase of 33 per cent in output; this saving averages 10 cents per thousand ton-miles. Applied at this rate the saving on the entire freight traffic of the zone in 1919 would have been $9,560,000.

For passenger service no data are at hand; a general consideration of the subject does not indicate a material saving in crew wages, and therefore none is assumed.

In switcher service the advantages of the electric locomotive in its quicker acceleration and quicker initial start are far-reaching. Tests made by the General Electric Co. at Erie show a movement per hour for the electric switcher of 1,000 trailing ton-miles as against 250 for a steam switcher of the same weight on drivers. The experience at the Oak Point yard of the

New Haven road proves that the relative output per locomotive-hour is more than 2 to 1. In view of these facts and of the characteristics of the machines, it is estimated that the electric switcher will do 50 per cent more work per hour than the steam switcher, and that consequently the wage account for the same total service will be reduced by 33 per cent.

Table 19 shows that the average wages per switcher-mile in the superpower zone are $0.60. The saving will then be $0.20 per mile, and the total saving in wages for the entire switcher traffic in the zone in 1919 (56,536,000 miles) would have been $11,310,000; this is greater than the saving in freight service.

TABLE 19.—*Analysis of crew wages for freight and switcher service, 1919.*

System.	Freight service.			Switcher service.		
	Wages per thousand ton-miles.	Train movement (millions of ton-miles).	Saving in wages under electric operation (25 per cent).	Wages per switcher-mile.	Train movement (thousands of switcher-miles).	Saving in wages under electric operation (33 per cent).
Boston & Maine	$0.40	6,600	$660,000			
Boston & Albany	.42	3,266	343,000			
New York, New Haven & Hartford and Central New England	.55	8,183	1,130,000	$0.60	4,900	$980,000
New York Central	.27	10,914	738,000	.45	5,086	760,000
Delaware & Hudson	.35	5,650	495,000	.69	1,143	265,000
Lehigh & Hudson River						
Erie	.29	5,707	415,000			
Delaware, Lackawanna & Western	.31	6,200	481,000	.58	3,200	620,000
Lehigh Valley	.50	5,093	635,000	.57	3,480	660,000
Central of New Jersey	.50	4,400	550,000	.57	3,000	570,000
Pennsylvania	.38	22,545	2,140,000	.61	14,024	2,850,000
Philadelphia & Reading	.49	10,900	1,330,000	.68	7,763	1,760,000
Baltimore & Ohio	.42	3,380	355,000			
		92,838	9,272,000		42,596	8,465,000

Average wage saving per thousand ton-miles, 10 cents; per switcher-mile, 20 cents.

CONSTRUCTION COSTS.

Form D gives the cost of electric equipment necessary to make the savings shown on Form C.

Form D.

Cost of catenary system and electric equipment, M. & N. system, R. division.

	Miles.	Cost.	
(1) Catenary system:			
(a) Single track	175	$2,013,000	
(b) Double track	68	1,700,000	
(c) Three-track	9	291,000	
(d) Four-track	42	1,625,000	
(e) Yards and sidings	221	1,658,000	
(2) Total			$7,287,000
(3) Substations kilowatts	*Capacity.* 82,100		4,926,000
(4) Locomotives:	*Number.*		
(a) Freight	43	3,440,000	
(b) Passenger	55	4,576,000	
(c) Switcher	41	2,657,000	
(5) Total	139		10,673,000
(6) Sum of specified items			22,886,000
(7) Allowance for unspecified items, 10 per cent of (6)			2,288,600
(8) Overhead, 20 per cent of (6)			4,577,200
(9) Total gross cost			29,751,800
(10) Credit for released steam locomotives	*Total tonnage.* 30,300		[a] 6,060,000
(11) Net cost			23,691,800

[a] Present value.

COST OF CATENARY SYSTEM.

The estimates of cost of the overhead structure assume the use of cross-catenary construction, with guyed tubular steel poles, main and secondary steel-strand messengers, two 4/0 copper contact wires, concrete foundations for all poles, and high-strength steel strand. Rails to be single-bonded with 300,000 circular mil bond; a 4/0 copper ground wire to be carried on the pole top. Poles all to carry tops and two cross arms, each with two pins.

The estimates of cost for this structure, based on prices in 1919, are derived from detailed estimates submitted by the General Electric Co., the Westinghouse Electric & Manufacturing Co., and the Ohio Brass Co. These estimates were for single, two, three, and four track line; for tangent, 2°, 4°, 6°, and 8° curvature; for yard track; and for branch lines. The estimates of the Ohio Brass Co. in particular give the quantities and prices of all items in complete detail.

These estimates have been carefully analyzed and checked up by comparison with the estimates of the Chicago Smoke Abatement Commission's report; they have also been submitted for criticism to engineers particularly versed in work of this class.

The estimates show good general agreement. Those of the Westinghouse Co. were slightly lower than those of the General Electric Co.; those of the Ohio Brass Co. were the highest. The costs given in the Chicago report, extended to the prices in 1919, are about the same as those of the General Electric Co.

The final costs determined for the 3,000-volt system are given in Table 20, which includes all costs of labor and material for the circuit outside of the substation for an average assumed alinement. The cost of the feeders is shown separately, the figures being taken from Table 24 below. Table 21 gives unit prices and quantities.

TABLE 20.—*Estimated cost of cross-catenary construction, with guyed steel poles, for 3,000-volt direct-current system.*

Per mile of road.

Number of tracks.	Size of feeder (circular mils).	Cost.		
		Catenary structure.	Feeder.	Total.
One	500,000	$9,300	$2,200	$11,500
Two	1,000,000	20,900	4,100	25,000
Three	1,250,000	27,000	5,300	32,300
Four	1,500,000	32,500	6,200	38,700
Five	1,500,000	38,000	6,200	44,200

Per track mile.

Yard tracks	....	$7,500	....	$7,500

TABLE 21.—*Quantities and unit prices for double-track 3,000-volt direct-current cross-catenary tangent, 300-foot span.*

Item.	Unit prices.	Per mile of line.	
		Quantity.	Cost.
Steel poles, guys, etc	7 cents per pound	30 tons	$4,200
Concrete	$20 per yard	130 yards	2,600
Excavation	$2 per yard	500 yards	1,000
Contact wires	23 cents per pound	13,500 pounds	3,110
Cross span, complete	$71 per span	17.6 spans	1,250
Messenger span, complete	$55 per span	35.2 spans	1,940
Work train, crew expenses			600
Labor for erection (except bond)			2,400
Bonds, labor and material			1,400
Steel strand, ⅝-inch	8 cents per foot		....
Steel strand, ⅜-inch	3 cents per foot		....
Labor:			
Foremen	$8.00 per day		....
Linemen	$6.00 per day		....
Helpers	$4.50 per day		....

The figures given in these tables are probably high, for when construction of this magnitude is undertaken all materials will be furnished at wholesale prices and the work will be systematized as a large-scale job. Moreover, there is no doubt that a simpler design can be made, which will save weight and cost through the use of higher-grade materials for certain parts of the structure.

COST OF SUBSTATIONS.

It being impracticable to lay out load curves for the several operating divisions, the substation capacity necessary (see item 3, Form D) has been based on an analysis of existing installations. The "capacity factor"—that is, the ratio of average annual output to total equipment capacity in present railroad substations—is used as the basis for determining the capacity of the proposed railroad substations within the zone.

Table 22, compiled from data of nearly all the electrified heavy-traction roads, shows that for a total use of 486,000,000 kilowatt-hours per year on eight roads there is a total substation capacity of 248,500 kilowatts, giving a ratio of average load to rated capacity of 22 per cent. For all the roads except the Long Island this ratio is singularly uniform, being within the limits of 21 to 26 per cent.

TABLE 22.—*Average energy output of heavy-traction substations per kilowatt of capacity.*

System.	Output (millions of kilowatt-hours).	Total sub-station capacity (kilowatts).	Kilowatt-hours per kilowatt of capacity.
New York Central	97	45,000	2,150
Long Island	76	56,000	1,360
New Haven	85	40,000	2,130
West Jersey & Seashore	24	12,000	2,000
Pennsylvania (Philadelphia-Paoli line)	24	12,000	2,000
Chicago, Milwaukee & St. Paul:			
Rocky Mountain division	66	29,000	2,270
Missoula division	60	30,500	1,970
Pennsylvania Terminal	54	24,000	2,250
	486	248,500	Av. 1,960

Plant capacity factor, 22 per cent.

Some of these roads have a lower traffic density than those of the superpower zone, particularly than those in the vicinity of the large cities, where yard service is heavy. To make some allowance for this condition a ratio of 25 per cent is taken as applying to the entire zone. The total substation capacity for any division is then obtained by dividing the estimated kilowatt-hours required for the service by 2,200. Peak loads will be taken care of by the overload capacity of 50 per cent for two hours and 200 per cent for five minutes.

The load factor of the individual substations will range from 15 to 60 per cent; nevertheless, owing to the variation of traffic throughout the year and the diversity between the various substation loads, the capacity should be based on a factor of 25 per cent.

A consideration of the power required for maximum trains and feeder capacity for the 3,000-volt direct-current system indicates an average spacing of substations of about 20 miles. This distance will vary for the different divisions, but this factor does not influence the estimates of cost for the substation, as they are based on a unit price.

The items that make up the unit price used in the estimate are given in Table 23. This price is based on large substations, having from three to ten motor-generator sets of 2,500 kilowatts or greater. The figures are derived from estimates submitted by the General Electric Co. and the Westinghouse Co.

TABLE 23.—*Estimated cost per kilowatt of 3,000-volt direct-current substation.*

Motor-generator sets, including exciters	$30
Transformers (110-kilovolt)	8
Switchboards (two 110-kilovolt incoming lines)	10
Building	8
Freight and installation	4
	60

COST OF 3,000-VOLT DIRECT-CURRENT FEEDERS.

The size of the direct-current feeders is based on a maximum pressure drop of 20 per cent, equal to 600 volts, for a train requiring 4,800 kilowatts halfway between substations, drawing 1,000 amperes from each substation. The following assumptions are made: Running rails, 100 pounds, with 300,000 circular mil bonds; resistance per mile of track, 0.03 ohm; two 4/0 copper trolley wires.

These data give the basis for the following table, which shows the feeder capacity required under average conditions and the cost per mile for the feeders erected.

TABLE 24.—*Capacity and cost of feeders.*

	Capacity (circular mils).	Cost per mile.
Single-track	500,000	$2,200
Two-track	1,000,000	4,100
Three-track	1,250,000	5,300
Four-track	1,500,000	6,200

COST OF ELECTRIC LOCOMOTIVES.

Item 4, Form D, gives the number and cost of electric locomotives required. The number called for is based on an annual mileage of 40,000 for freight, 75,000 for passenger, and 40,000 for switcher locomotives. The cost of the electric locomotives is based on estimates made by the General Electric Co. and the Westinghouse Co. for freight, passenger, and switcher service in 1919. These estimates are stated in cost per pound for the three classes; they are substantially the same for both companies for locomotives of the same kind. The unit costs used are 40 cents per pound of total weight for freight locomotives and switchers and 45 cents for passenger locomotives, equivalent to $800 per ton on drivers for freight locomotives and switchers and $1,300 per ton on drivers for passenger locomotives. The total weight on drivers of the electric locomotives is the product of their number by the average weight on drivers of the steam locomotives on the division.

NUMBER OF ELECTRIC LOCOMOTIVES REQUIRED.

The electric service covered by the estimates is the power equivalent of the present steam service in the zone. The year 1919 is taken for comparison, as it is the latest complete calendar year before the beginning of this investigation. The number of electric locomotives required for the service should in the final analysis be determined by a study of train movements on each division. This study was impracticable in the present investigation, and therefore a shorter method had to be used. The plan followed was to determine the average number of miles per year per electric locomotive required for freight, passenger, and switcher service. This average mileage was determined by comparing the mileage records of the electric locomotives in certain operating electric systems in the United States with the mileage records of the steam locomotives in the zone. To show why the electric locomotive gives the greater mileage, a distribution of locomotive-hours for electric service was deduced from that of the present steam service by modifying it to accord with the proved fact of the greater availability of the electric locomotive. This procedure fixed the same number of miles per year in each class of service for the entire zone; conditions of unified operation are thus implied. This leads to some irregularities in the proportional number of steam and electric locomotives on certain of the smaller roads, but the figures are intended as averages, not to apply exactly to each operating division. These smaller roads will represent less than 10 per cent of the traffic.

The assignment of the same locomotive mileage to the single-track roads with low traffic density as to the divisions having denser traffic is not strictly correct; the great variation in annual mileage of the steam locomotives of these divisions reflects the differences in traffic conditions. In order to make some allowance for the light-traffic divisions the minimum number of electric locomotives for each division is fixed at 50 per cent of the corresponding number of steam locomotives, even if the number based on mileage is less than 50 per cent.

MILEAGE.

Table 25 gives the steam mileage for 1919 of the freight and passenger service on the principal systems. Table 26 gives the available statistics on annual mileage of electric locomotives; the average for freight service is approximately 40,000 miles. The only extensive system that keeps records separately for passenger service is the New Haven, with a mileage of 73,000; this mileage can be increased with complete electric operation. The New York Central and the Pennsylvania Tunnel & Terminal are operating a short-haul service which gives no opportunity to make great mileage.

TABLE 25.—*Average steam-locomotive mileage of principal systems in superpower zone, 1919.*

[Based on total number of locomotives owned.]

System.	Freight.	Passenger.
New Haven	15,200	30,500
New York Central	17,300	34,500
Delaware & Hudson	20,600	30,500
Lehigh & Hudson River	13,400	24,100
Erie	18,900	30,000
Delaware, Lackawanna & Western	22,800	39,000
Lehigh Valley	14,700	30,500
Central of New Jersey	16,600	26,200
Pennsylvania, eastern lines	19,900	42,500
Philadelphia & Reading	21,800	33,500
Baltimore & Ohio	16,600	38,000
Average	18,000	32,700

TABLE 26.—*Average annual mileage of electric locomotives.*

[Based on total number of locomotives owned.]

System.	Freight.	Passenger.	All.
New Haven	33,500	73,000	55,000
New York Central		34,500	34,500
Pennsylvania (New York Terminal)		39,300	39,300
Norfolk & Western	49,000		49,000
Butte, Anaconda & Pacific	43,500		43,500
Chicago, Milwaukee & St. Paul			49,000

LOCOMOTIVE-HOURS.

Records of the distribution of locomotive-hours for a number of the roads within the superpower zone are available, particularly those of the Pennsylvania, of which eight operating divisions are included within the zone; they reflect the entire range of service, from the heaviest traffic on the New York division to the light traffic of the West Jersey & Seashore and Sunbury divisions. The Pennsylvania is taken as an example of the best average operating results.

The statistics of the operations of the Pennsylvania system for 1919 within the superpower zone are given in Table 27, which sets forth the proportion of the time of all serviceable locomotives and of all assigned locomotives, in accordance with the schedule of time specified by the United States Railroad Administration in its "Operating statistics sheets." Item 1 of the table includes items 1 and 2 of the operating statistics sheets and represents the total time that locomotives are in "hands of crew," including time between termini, time waiting at termini, and time to and from engine house. From 90 to 95 per cent of this is productive time—that is, time between termini. Item 2a represents time required for cleaning fires, washing boilers, ash-pit work, inspection, running repairs, etc. Item 2b represents time spent in waiting at engine house for call to service after maintenance forces have delivered locomotive to transportation forces. All this is wasted time. Item 3 gives the total time in the engine house, the sum of 2a and 2b. Item 4 ("stored hours") represents surplus equipment for which there is no call. Item 5 shows the total serviceable hours taken both as 100 per cent and as a percentage of total assigned locomotive hours. The differences between 100 per cent and 71, 69, and 80 per cent give for the three services respectively the proportion of total time in the shops under general repairs or awaiting such repairs.

TABLE 27.—*Average distribution of locomotive-hours in 1919 on all divisions of the Pennsylvania system within the superpower zone, in per cent.*

Item.	Serviceable locomotive-hours.			Total locomotive-hours.		
	Freight.	Passenger.	Switcher.	Freight.	Passenger.	Switcher.
1. Crew-hours	47	39	61	33	27	49
2. Engine house:						
(*a*) Mechanical department	31	37	18	22	26	14
(*b*) Transportation department	17	22	18	12	15	15
3. Total engine-house time (2a+2b)	48	59	36	34	41	29
4. Stored hours	5	2	3	4	1	2
5. Total serviceable hours	100	100	100	71	69	80

The average utilization of the locomotives in the zone as a whole is not as good as on the Pennsylvania. Table 28 gives the ratio of "crew-hours" to total serviceable hours (item 1 of Table 27) for eight of the systems within the zone, with the total number of assigned locomotives. For the weighted average of all these systems the ratio of crew-hours to total serviceable hours is 37, 30, and 50 per cent for freight, passenger, and switcher locomotives, respectively, as compared with 47, 39, and 61 per cent for the Pennsylvania.

TABLE 28.—*Average distribution of locomotive-hours of representative railroads within the superpower zone, 1919.*

System.	Total number of locomotives.	Ratio of crew-hours to total serviceable hours (per cent).		
		Freight.	Passenger.	Switcher.
Pennsylvania	1,800	47	39	61
Philadelphia & Reading	1,000	49	34	52
Central of New Jersey	600	39	40	54
Delaware, Lackawanna & Western	750	39	28	51
Erie	1,450	32	25	43
New York Central	3,500	33	29	53
Lehigh Valley	1,000	27	25	38
Delaware & Hudson	500	33	24	49
Total or weighted average	10,600	37	30	50
Equivalent number of crew-hours per year	....	3,250	2,630	4,380

A direct comparison of time is afforded by the New Haven system. Table 29 sets forth the figures for both steam and electric operation on that system for five months of 1919.

TABLE 29.—*Ratio of crew-hours to total serviceable hours under steam and electric operation of the New Haven system, 1919.*

Month.	Freight.		Passenger.		Switcher.	
	Electric.	Steam.	Electric.	Steam.	Electric.	Steam.
March	43	27	45	29	67	48
April	50	26	45	28	68	47
September	63	40	47	29	81	54
October	62	39	50	28	81	56
November	49	39	42	27	87	53
Average	54	34	46	28	77	52

Ratio of number of serviceable electric locomotives required to do the same work:
Freight, $34 \div 54 = 63$ per cent.
Passenger, $28 \div 46 = 61$ per cent.
Switcher, $52 \div 77 = 68$ per cent.

What can be done with motive power in proportion to the service required is shown in Table 30, which gives the distribution of serviceable locomotive-hours on the Norfolk & Western. Here the locomotives are in road service 74 per cent of the total time and the crew-hours are 76 per cent. This is to be compared with 33 per cent as the average for freight service on the Pennsylvania and 28 per cent for all the roads in the zone—that is, one electric locomotive in the Norfolk & Western freight service does as much work as is done in the rest of the zone by 2.65 steam locomotives.

TABLE 30.—*Distribution of electric locomotive-hours in freight service on Norfolk & Western Railway, in per cent.*

In road service		74.0
Terminal delay in hands of crew		2.3
Engine house:		
Inspection and repairs (motive-power department)	14.8	
Waiting (transportation department)	8.9	
		23.7
Total serviceable hours		100
Recapitulation by departments:		
Transportation		85.2
Motive power		14.8

From Table 27 the figures in Table 31 are deduced, showing the estimated average distribution of locomotive-hours of electric locomotives. In this table the crew-hours for freight service are taken at 77 per cent of the corresponding figure for steam service of the Pennsylvania. This assumes that on the average an electric locomotive will yield 30 per cent more trailing ton-miles per crew-hour than the average steam locomotive—an assumption based on data of operation of several electric roads. This result is attained partly by higher speed and heavier trains, or both; in minor part by the elimination of the loaded tender and nondriver weight of the steam locomotives; and largely by standardization of locomotive types and pooling of locomotives.

In passenger service the electric crew-hour is taken as 11 per cent more productive than the steam; this result will be attained in great measure by the widespread use of multiple-unit cars for the short runs in the extensive suburban service of the zone and by better-sustained average speed for other passenger trains. The average speed of passenger trains on the Pennsylvania system is only 17.5 miles per crew-hour; a uniform increase of 11 per cent would mean an average of less than 20 miles per hour, a speed that is now exceeded by a number of steam divisions. For switcher service the electric crew-hour is taken at 1.50 times as productive as the steam. The service on the New Haven line and the General Electric Co.'s tests at Erie and Schenectady give higher ratios.

Item 2a, Table 31, showing time in engine house for repairs, etc., is taken at about one-third of the steam time. For item 2b, time awaiting call, the ratio to crew-hours is taken at approximately the same as in steam service. This estimate is moderate or perhaps low, for with half as many locomotives in service the waits must necessarily be shorter, and moreover the use of classes of uniform locomotives will save much of this delay. The ratio of serviceable to total electric locomotive-hours is pretty well established at about 90 per cent. With these assumptions, all of which tend to minimize the savings of unified electric operation, the Pennsylvania system could be operated electrically in 61, 66, and 54 per cent of the serviceable hours, or 48.5, 51, and 48 per cent of the total hours now required for the steam operation of the freight, passenger, and switcher services, respectively.

TABLE 31.—*Estimated distribution of electric locomotive-hours, in percentages of time required for steam operation of the Pennsylvania system.*

Item.	Freight.		Passenger.		Switcher.	
	Steam.	Electric.	Steam.	Electric.	Steam.	Electric.
Crew-hours	47	36	39	35	61	41
Engine house:						
a. Mechanical department	31	10	37	12	18	6
b. Transportation	17	13	22	18	18	12
Total engine house (2a+2b)	48	23	59	30	36	18
Stored	5	2	2	1	3	1
Total serviceable hours	100	61	100	66	100	60
Ratio of serviceable to total hours	71	90	69	90	80	90
Total hours of assigned locomotives	141	68	144	74	125	67

Relative number of electric locomotives required:
Freight, 68÷141=48.5 per cent.
Passenger, 74÷144=51.0 per cent.
Switcher, 67÷125=53.5 per cent.

Table 32, taken from Table 31, sums up the estimated schedule for electric operation. The crew-hours amount to 59, 53, and 76 per cent of the serviceable hours. These figures are low, in the opinion of several electric operating men, who claim that crew-hours should be taken at 70 per cent of total hours, equivalent to 78 per cent of serviceable hours.

TABLE 32.—*Distribution of electric locomotive hours.*

Item.	Freight.	Passenger.	Switcher.
Crew-hours	59	53	76
Engine house:			
(a) Mechanical department	17	18	11
(b) Transportation department	21	27	11
Total engine house	38	45	22
Stored	3	2	2
Total serviceable hours	100	100	100

From a direct comparison of the mileage of Tables 25 and 26 and the above analysis of locomotive-hours the annual mileage of electric locomotives is taken at 40,000 for freight locomotives, 75,000 for passenger locomotives, and 40,000 for switchers.

TOTAL COST.

Item 5 of Form D, the sum of items 2, 3, and 4, gives the total estimated cost of the specified items and accounts for 90 to 95 per cent of the total cost of the work. Table 33, giving the itemized costs of the Chicago terminal electrification, shows that the other items amount to less than 8 per cent. These unspecified items are principally changes in signal system, provision against electrolysis, and certain minor items. Item 7 of Form D is an allowance of 10 per cent for these unspecified costs.

TABLE 33.—*Cost of items of construction and equipment involved in the electrification of Chicago terminals, exclusive of power station and transmission system.*

Item.	2,400-volt direct-current.		11,000-volt alternating-current.	
	Total.	Per cent.	Total.	Per cent.
Substations	$5,660,000	4.0	$2,025,000	1.5
Switching stations	1,522,000	1.1	573,000	.4
Overhead contact system	33,895,000	23.8	28,142,000	20.3
Bridge warnings	1,072,000	....	1,072,000	....
Return circuit	6,070,000	4.3	4,446,000	3.2
Prevention of inductive effects and electrolysis	....	....	997,000	....
Telephone system	272,000	....	272,000	....
Electric locomotives, multiple-unit equipment, work and inspection equipment	84,004,000	59.0	91,704,000	66.0
Spare parts	503,000	....	485,000	....
Changes in overhead structures	834,000	....	834,000	....
Changes in wire lines	2,028,000	....	2,028,000	....
Changes in signal system	6,694,000	....	6,111,000	....
	142,554,000	100.0	138,689,000	100.0
Summary:				
Specified items	....	92.2	....	91.4
Unspecified items	....	7.8	....	8.6
	....	100.0	....	100.0

ENGINEERING, CONTINGENCIES, AND INTEREST.

Item 8 of Form D covers overhead allowance of 20 per cent for engineering, contingencies, and interest. This construction will be essentially work of duplication; the units will be identical both for substation equipment and for locomotives. The estimate assumes not special production but quantity production, which will reduce the percentage required for engineering and for contingencies. Similarly, the allowance for interest should not be as great as for construction work undertaken by a single company, as the work would be done on the general credit of the combined railroad systems; money will be obtained as needed, and the construction period, during which interest must be carried, will be minimized; in fact, much of the cost represents equipment, payments for which can fairly be assumed to be made toward the end of the period of construction.

RELEASED LOCOMOTIVES.

Item 9 of Form D gives the total gross cost of electrification, which is reduced by the credit for released steam locomotives, given by item 10. This credit is based on the assumption that all steam locomotives released within the superpower zone can be used. Electrification will be progressive, and it is a reasonable assumption that locomotives as released from one division will be transferred either to another division or to another road. The amount of the credit is determined by assuming that the average condition of the locomotives is 50 per cent new, probably an underestimate in view of the fact that much of the equipment has been bought within the last ten years. The value of a new locomotive in 1919 is taken at 18 cents per pound of total weight, and the salvage value at 2 cents per pound. These figures are based on the elaborate estimates of the equipment committee of the President's Conference Committee of Steam Railroad Companies, whose reports embody the fullest examination yet made of the value and cost of steam locomotives and of their reproduction cost. From these assumptions is obtained a net value of 10 cents per pound of total weight as the amount to be credited. The average ratio of total weight to weight on drivers is found to be 1.5 for freight, passenger, and switcher locomotives, in the proportions that now prevail in the zone; this fixes the value per pound on drivers of the released steam locomotives at 15 cents.

Deduction of item 10 gives the net cost of electrification; the percentage that the saving from electric operation bears to this total cost determines whether any division is susceptible of economical electrification.

CONCLUSIONS.

The study described above has been made for all the class 1 railroad systems within the superpower zone except the Ulster & Delaware, the New York, Ontario & Western, and the Western Maryland. The first two were omitted, after a preliminary examination, because their traffic was too light to warrant electrification. The Western Maryland was omitted because only a small part of its trackage is within the zone; the preliminary examination, however, indicates that the Western Maryland traffic would justify electrification. There remained, then, 13 railroad systems[1] in the zone that were studied in accordance with Forms C and D (pp. 59, 67). In this study it was not possible to adhere strictly to the limits of every operating division reported by the railroads, and some divisions were therefore consolidated into routes. The number of divisions or routes ranged from one on the Boston & Maine to nine on the Pennsylvania and aggregated 40 for the 13 roads.

The results of the study are given in figures 14 and 15, which show for each of the 40 divisions the annual saving, in percentage of the net cost of electrification, plotted against the energy required, in kilowatt-hours per year, together with the accumulated average percentage of saving for the divisions as grouped. Figure 14 shows the saving exclusive of the saving in crew wages, and the divisions are arranged in the order of percentages. With these results as the criterion of economical electrification the "selected divisions" are assumed to be all that show a saving of 9 per cent or more. The group of divisions thus selected shows an average saving of 11.4 per cent. It includes 30 of the 40 divisions examined, comprised in 11 of the 13 systems shown in Plate VI. Figure 15 shows the saving including the wage saving for the 40 divisions arranged in the same order as in figure 14. For the "selected divisions" these savings range from 10.6 to 19 per cent and average 14.2 per cent. The total energy required annually for these 30 divisions will be 4,400 million kilowatt-hours, and the maximum demand approximately 850,000 kilowatts.

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[1] The Boston & Albany was included with the New York Central, and the Long Island with the Pennsylvania.

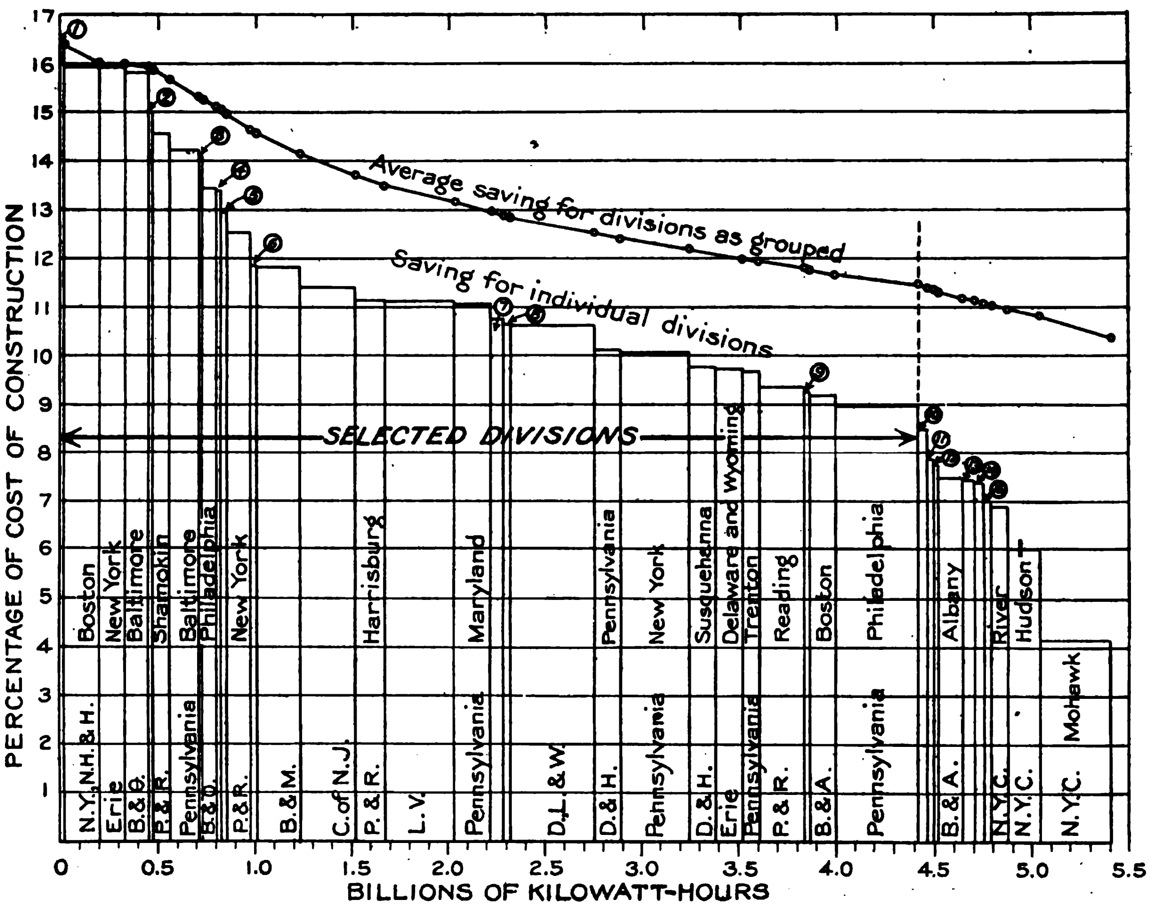
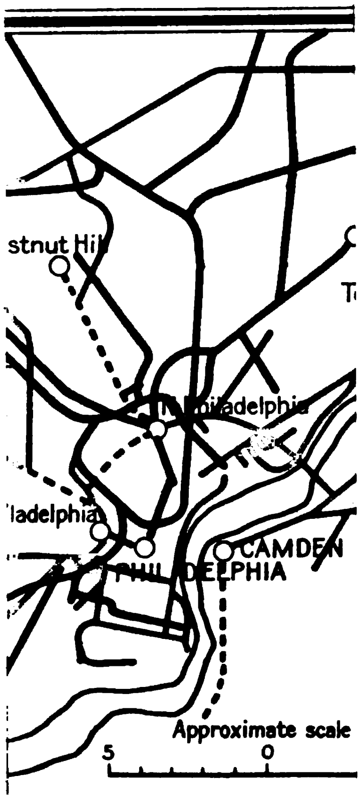


FIGURE 14.—Saving effected by electrification of heavy-traction railroads, in percentage of construction cost, not including saving in wages. Each column represents a railroad division or route. 1, New York and New Jersey division, Erie; 2, Northern division, Erie; 3, Greenwood Lake division, Erie; 4, Jefferson division, Erie; 5, Schuylkill division, Pennsylvania; 6, Springfield division, N. Y., N. H. & H.; 7, Maybrook division, N. Y., N. H. & H.; 8, Philadelphia division, P. & R.; 9, New York, Susquehanna, and Western division, Erie; 10, Cumberland Valley division, Pennsylvania; 11, Atlantic City division, P. & R.; 12, Wilmington and Columbia division, P. & R.; 13, Sunbury division, Pennsylvania; 14, New Jersey and Seashore division, Pennsylvania; 15, Lehigh & Hudson River R. R. Other divisions are indicated on the diagram.

The low percentage of saving shown by the divisions not included in the selected group, except those of the New York Central, is due to light traffic. On the New York Central the train cost of transportation, the cost of maintaining steam locomotives, and the cost of coal per mile are lower than on any other system, owing in part to the fact that this is a water-level road with a large amount of through traffic; these are favorable conditions for economical steam operation and therefore afford less opportunity for saving by electrification.

The importance of the 30 selected divisions as compared with all the divisions of class 1 railroads within the zone is shown in Table 34.

PHIA AND VICINITY



R ZONE TO

TABLE 34.—*Data for all divisions and selected divisions of class 1 railroads in the superpower zone.*

	All divisions.	Selected divisions.	
		Quantity.	Per cent.
Length of road.........miles..	13,396	6,395	48
Length of main track.........do....	21,021	11,296	53
Length of yard track.........do....	12,233	7,831	64
Length of all track.........do....	33,254	19,127	58
Freight service.........millions of ton-miles..	95,629	71,460	75
Passenger service.........thousands of train-miles..	88,026	52,864	60
Switcher service.........thousands of locomotive-miles..	56,536	41,572	74
All locomotives.........thousands of miles..	9,521	6,542	69
Coal used on locomotives.........tons..	18,405,000	13,313,000	72

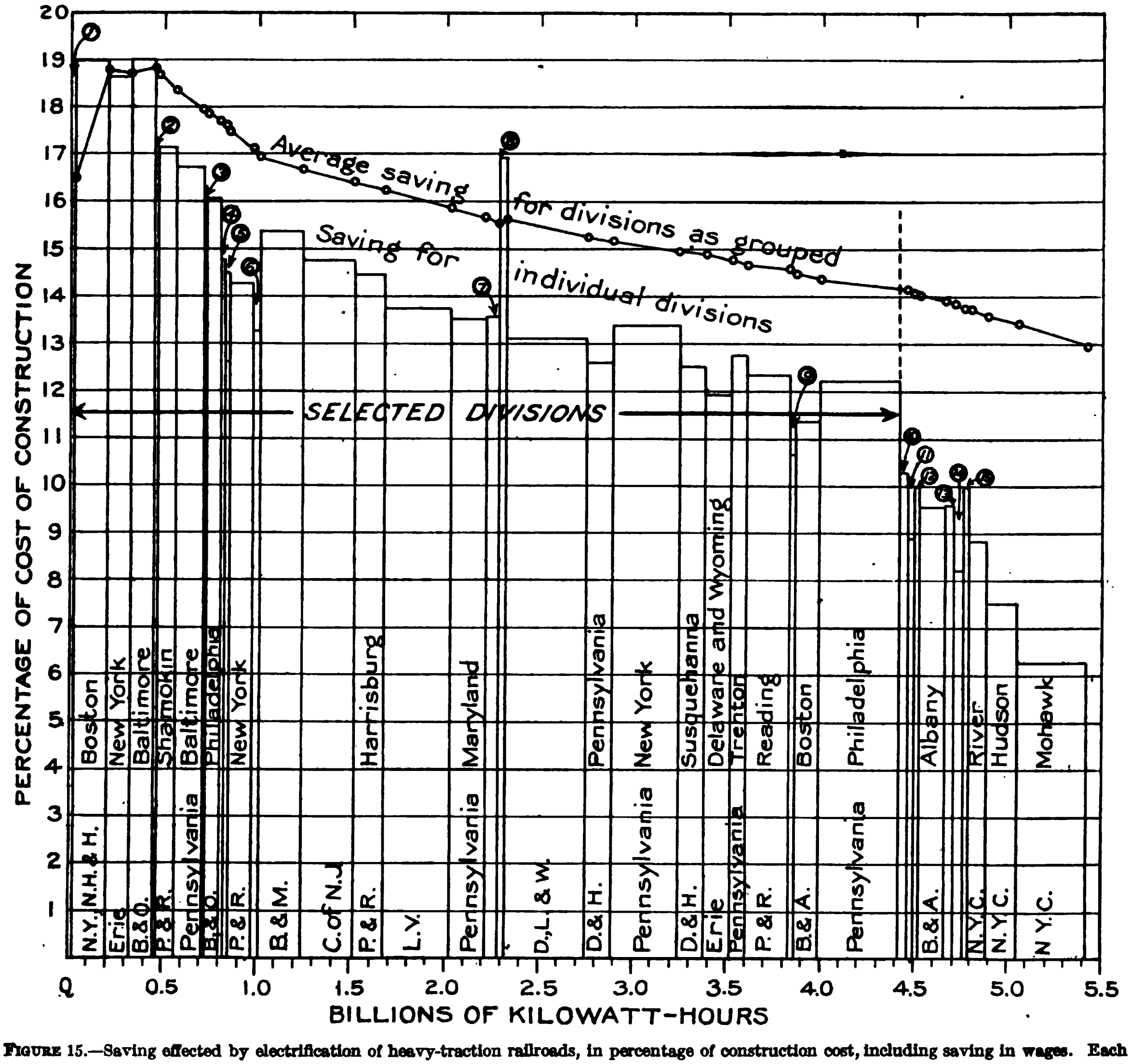


FIGURE 15.—Saving effected by electrification of heavy-traction railroads, in percentage of construction cost, including saving in wages. Each column represents a railroad division or route. For explanation of numbers see figure 14.

Table 35 summarizes for the 11 systems that include the 30 selected divisions the net estimated cost of construction and electric equipment and the net savings from operation, both including and excluding saving in wages. The net cost of electrification of all the selected divisions is $570,000,000, and the annual net saving in operation, including the saving in wages, is $81,000,000, equal to an average of 14.2 per cent for the entire group, ranging from 10.6 per cent for the New York, Susquehanna, and Western division of the Erie to 19 per cent for the New Haven-Boston route of the New Haven.

TABLE 35.—*Summary of electric operation on selected divisions.*

System and division.	Net cost of construction.	Net reduction in annual cost of operation.			
		Including crew wages.		Excluding crew wages.	
		Amount.	Percentage of cost of construction.	Amount.	Percentage of cost of construction.
Boston & Maine	$28,862,500	$4,431,200	15.35	$3,411,200	11.82
Boston & Albany:					
Boston	18,237,700	2,071,200	11.36	1,672,700	9.17
New York, New Haven & Hartford and Central New England:					
Boston	20,300,500	3,852,500	18.98	3,235,000	15.93
Springfield	5,279,300	700,000	13.26	627,000	11.88
Maybrook	10,812,100	1,465,200	13.55	1,165,200	10.78
	36,391,900	6,017,700	16.54	5,027,200	13.81
Delaware & Hudson:					
Susquehanna	17,885,700	2,223,300	12.43	1,742,700	9.75
Pennsylvania	12,719,900	1,600,500	12.58	1,287,500	10.10
	30,605,600	3,823,800	12.49	3,030,200	9.90
Erie:					
New York (main)	19,597,100	3,655,600	18.65	3,119,100	15.92
Greenwood Lake	3,268,600	466,060	14.26	459,800	14.07
Northern	1,891,000	285,000	15.07	284,000	15.02
New York and New Jersey	1,856,400	304,675	16.42	303,800	16.37
Delaware and Wyoming	16,295,700	1,926,200	11.82	1,582,500	9.72
Jefferson	2,987,900	441,300	14.77	400,400	13.40
New York, Susquehanna, and Western	7,372,300	784,900	10.65	682,200	9.25
	53,269,000	7,863,735	14.76	6,831,800	12.82
Delaware, Lackawanna & Western	50,780,700	6,654,500	13.10	5,394,500	10.62
Lehigh Valley	45,884,800	6,310,700	13.75	5,105,200	11.13
Central of New Jersey	31,997,800	4,711,300	14.72	3,651,300	11.41
Pennsylvania:					
New York	46,494,100	6,207,300	13.35	4,677,700	10.06
Trenton	14,734,300	1,780,300	12.08	1,425,300	9.67
Philadelphia	45,597,800	5,562,400	12.20	4,074,000	8.93
Schuylkill	6,097,500	883,400	14.49	790,300	12.96
Maryland	23,691,800	3,201,200	13.51	2,627,100	11.09
Baltimore	23,673,900	3,953,300	16.70	3,364,900	14.21
	160,289,400	21,587,900	13.47	16,959,300	10.58
Philadelphia & Reading:					
New York	16,913,100	2,407,500	14.23	2,118,800	12.53
Philadelphia	7,682,000	1,299,800	16.92	814.800	10.61
Reading	29,540,200	3,640,100	12.32	2,756,100	9.33
Shamokin	15,981,900	2,734,700	17.11	2,322,700	14.53
Harrisburg	15,151,500	2,194,400	14.48	1,690,400	11.16
	85,268,700	12,276,500	14.40	9,702,800	11.38
Baltimore & Ohio:					
Philadelphia	18,821,100	3,579,000	19.01	2,979,700	13.43
Baltimore	9,675,800	1,553,400	16.05	1,299,400	15.83
	28,496,900	5,132,400	18.01	4,279,100	15.02
Grand total	570,085,000	80,880,935	14.19	65,065,300	11.41

The data of roadbed, equipment, and operation, both for steam and for electricity, of the selected divisions are summarized in Tables 36 to 42.

TABLE 36.—*Track mileage of selected divisions.*

System.	Road.	Main.	Yard.	Total.
Boston & Maine	278	504	295	799
Boston & Albany	201	368	228	596
New York, New Haven & Hartford	329	720	495	1,215
Delaware & Hudson	377	666	337	1,003
Erie	715	1,146	725	1,871
Delaware, Lackawanna & Western	551	1,030	682	1,712
Lehigh Valley	544	985	751	1,736
Central of New Jersey	315	597	658	1,255
Pennsylvania	1,503	2,733	2,107	4,840
Philadelphia & Reading	1,231	1,927	1,246	3,173
Baltimore & Ohio	351	620	307	927
	6,395	11,296	7,831	19,127

TABLE 37.—*Data of steam operation on selected divisions.*

System.	Total.			Per mile of road.				
	Locomotives.	Traffic (thousands of locomotive-miles).	Coal (thousands of tons).	Locomotives.	Traffic (locomotive-miles).			
					Freight.	Passenger.	Sum.	Total.[a]
Boston & Maine	363	9,250	630	1.31	16,730	5,750	22,480	33,270
Boston & Albany	192	5,550	365	.95	7,110	13,830	20,945	27,610
New York, New Haven & Hartford	456	11,295	825	1.39	12,770	13,900	26,680	34,340
Delaware & Hudson	314	6,940	765	.83	12,900	2,470	15,380	18,410
Erie	568	11,346	1,093	.79	6,140	6,510	12,650	15,870
Delaware, Lackawanna & Western	570	13,900	1,400	1.03	11,250	8,170	19,420	25,230
Lehigh Valley	619	10,550	1,103	1.14	8,470	4,520	13,000	19,390
Central of New Jersey	535	10,000	860	1.70	12,700	9,520	22,220	31,750
Pennsylvania	1,655	48,039	3,433	1.10	8,360	14,750	23,110	31,960
Philadelphia & Reading	960	22,353	2,200	.78	7,380	4,270	12,460	18,160
Baltimore & Ohio	310	8,122	640	.88	7,170	8,620	15,800	23,140
Total or weighted average	6,542	156,345	13,313	1.023	9,150	8,590	17,740	24,450

System.	Per mile of road.		Per mile of all track.			Road locomotive-miles per mile of main track.	Switcher locomotive-miles per mile of yard track.
	Coal (tons).	Gross freight traffic (thousands of ton-miles).	Locomotives.	Total traffic (locomotive-miles).[a]	Coal (tons).		
Boston & Maine	2,266	15,100	0.455	11,580	789	12,400	10,170
Boston & Albany	1,816	6,490	.322	9,310	612	11,430	5,880
New York, New Haven & Hartford	2,507	14,800	.375	9,300	679	12,190	5,090
Delaware & Hudson	2,030	15,000	.313	6,920	762	8,710	3,390
Erie	1,530	8,000	.303	6,060	584	7,890	3,180
Delaware, Lackawanna & Western	2,540	11,300	.332	8,120	818	10,400	4,690
Lehigh Valley	2,030	9,400	.356	6,080	635	7,180	4,630
Central of New Jersey	2,730	14,600	.426	7,970	685	11,720	4,560
Pennsylvania	2,284	13,090	.342	9,920	709	10,430	6,310
Philadelphia & Reading	1,790	9,500	.302	7,050	693	7,960	5,630
Baltimore & Ohio	1,820	9,600	.334	8,760	691	8,940	8,390
Total or weighted average	2,082	11,320	.342	8,170	696	10,040	5,480

[a] Includes switcher locomotive-miles.

TABLE 38.—*Data of electric operation on selected divisions.*

System.	Total.			Per mile of road.			Per mile of all track.		
		Substations.			Substations.			Substations.	
	Number of locomotives.	Capacity (thousands of kilowatts).	Energy required annually (millions of kilowatt-hours).	Number of locomotives.	Capacity (kilowatts).	Energy required annually (thousands of kilowatt-hours).	Number of locomotives.	Capacity (kilowatts).	Energy required annually (thousands of kilowatt-hours).
Boston & Maine	212	102	224	0.763	367	806	0.265	128	280
Boston & Albany	107	59	129	.532	294	642	.180	99	216
New York, New Haven & Hartford	233	120	297	.708	366	903	.192	99	245
Delaware & Hudson	163	125	276	.432	333	731	.163	125	275
Erie	313	156	340	.438	218	475	.167	83	182
Delaware, Lackawanna & Western	295	197	433	.535	358	785	.172	115	253
Lehigh Valley	236	168	367	.434	307	674	.136	96	211
Central of New Jersey	215	130	289	.683	414	917	.171	104	230
Pennsylvania	959	561	1,232	.638	373	820	.198	116	255
Philadelphia & Reading	488	289	635	.396	235	516	.153	91	200
Baltimore & Ohio	172	91	201	.490	260	571	.186	99	216
Total or weighted average	3,393	1,998	4,423	.531	312	692	.177	104.4	231

TABLE 39.—*Coal saved by electric operation on selected divisions.*

System.	Quantity (thousands of tons).				Percentage of steam locomotive coal.			
	Freight.	Passenger.	Switcher.	All.	Freight.	Passenger.	Switcher.	All.
Boston & Maine	253	48	105	406	63.3	60.0	70.0	64.4
Boston & Albany	93	105	38	236	60.8	65.5	73.7	64.7
New York, New Haven & Hartford	247	176	105	528	61.3	62.8	73.6	64.0
Delaware & Hudson	382	43	64	489	61.4	70.0	78.9	64.0
Erie	363	258	133	754	62.9	72.4	82.7	63.9
Delaware, Lackawanna & Western	590	225	152	967	65.6	75.0	76.0	69.1
Lehigh Valley	422	126	188	736	62.4	67.5	78.3	66.7
Central of New Jersey	276	140	155	571	60.0	70.0	77.5	66.4
Pennsylvania	887	804	509	2,200	60.0	64.5	71.8	64.1
Philadelphia & Reading	1,035	264	265	1,564	71.6	67.9	72.7	71.1
Baltimore & Ohio	211	128	101	440	67.6	67.8	72.4	68.7
Total or weighted average	4,758	2,317	1,815	8,890	64.1	67.2	74.4	66.8
Percentage	54	26	20	100				

TABLE 40.—*Energy required for electric operation on selected divisions, in thousands of kilowatt-hours.*

System.	Freight.	Passenger.	Switcher.	All.
Boston & Maine	147,000	32,000	45,000	224,000
Boston & Albany	60,000	55,600	13,400	129,000
New York, New Haven & Hartford	155,500	103,800	37,800	297,100
Delaware & Hudson	240,000	18,600	17,100	275,700
Erie	213,400	98,600	27,800	339,800
Delaware, Lackawanna & Western	310,000	75,000	48,000	433,000
Lehigh Valley	254,000	60,600	52,200	366,800
Central of New Jersey	184,000	60,000	45,000	289,000
Pennsylvania	590,200	443,200	199,600	1,233,000
Philadelphia & Reading	410,900	125,100	99,300	635,300
Baltimore & Ohio	101,400	60,500	38,700	200,600
	2,666,400	1,133,000	623,900	4,423,300
Percentage	60.30	25.60	14.10	100.00

TABLE 41.—*Cost of electric track facilities and equipment of selected divisions, in thousands of dollars.*

System.	Mileage.		Specified items.				Unspecified items (10 per cent).	Overhead (20 per cent).	Total gross cost.	Credit for released steam locomotives.	Net cost.
	Road.	All track.	Track distribution system.	Sub-stations.	Loco-motives.	Sum.					
Boston & Maine	278	799	8,397	6,120	14,208	28,725	2,872	5,745	37,342	8,480	28,862
Boston & Albany	201	596	5,917	3,540	7,972	17,429	1,743	3,486	22,658	4,420	18,238
New York, New Haven & Hartford	329	1,215	12,352	7,218	16,233	35,803	3,580	7,161	46,544	10,152	36,392
Delaware & Hudson	377	1,003	10,451	7,524	12,737	30,712	3,071	6,142	39,925	9,320	30,605
Erie	715	1,871	19,032	9,360	23,338	51,730	5,173	10,346	67,249	13,980	53,269
Delaware, Lackawanna & Western	551	1,712	17,131	11,820	20,388	49,339	4,934	9,868	64,141	13,360	50,781
Lehigh Valley	544	1,736	17,002	10,020	20,074	47,096	4,710	9,419	61,225	15,340	45,885
Central of New Jersey	315	1,255	11,834	7,824	14,048	33,706	3,371	6,741	43,818	11,820	31,998
Pennsylvania	1,503	4,840	46,555	33,612	75,871	156,038	15,604	31,208	202,850	42,560	160,290
Philadelphia & Reading	1,231	3,173	31,870	17,340	34,489	83,699	8,370	16,740	108,809	23,540	85,269
Baltimore & Ohio	351	927	9,695	5,484	12,634	27,813	2,781	5,563	36,157	7,660	28,497
	6,395	19,127	190,236	119,862	251,992	562,090	56,209	112,419	730,718	160,632	570,086
Percentage	....	....	26.0	16.4	34.5	76.9	7.7	15.4	100.0	22.0	78.0

TABLE 42.—*Comparative cost of steam and electric operation on selected divisions, in thousands of dollars.*

System.	Net cost of electric construction and equipment.	Cost of steam operation.		Cost of electric operation.			Saving by electric operation.		
		Coal.	Locomotive maintenance.	Energy.	Locomotive maintenance.	Distribution and substations.	Wage saving.	Total.	Ratio to cost of construction (per cent).
Boston & Maine	28,862	3,780	3,170	2,240	721	578	1,020	4,431	15.4
Boston & Albany	18,238	2,190	1,601	1,290	426	402	399	2,072	11.4
New York, New Haven & Hartford	36,392	4,949	4,737	2,971	849	838	991	6,019	16.5
Delaware & Hudson	30,605	4,208	2,984	2,757	677	727	795	3,826	12.5
Erie	53,269	5,467	6,913	3,398	936	1,216	1,032	7,862	14.8
Delaware, Lackawanna & Western	50,781	7,000	5,004	4,330	1,086	1,194	1,260	6,654	13.1
Lehigh Valley	45,885	5,514	5,170	3,668	869	1,041	1,205	6,311	13.8
Central of New Jersey	31,998	4,300	3,800	2,890	735	824	1,060	4,711	14.7
Pennsylvania	160,290	17,162	19,797	12,330	4,125	3,547	4,628	21,585	13.5
Philadelphia & Reading	85,269	10,998	8,976	6,353	1,819	2,099	2,574	12,277	14.4
Baltimore & Ohio	28,497	3,202	4,386	2,006	667	635	853	5,133	18.0
	570,086	68,770	66,538	44,233	12,910	13,101	15,817	80,881	14.2

Table 43 gives the comparative data for steam and electric operation, in accordance with Form C, for all the selected divisions within the zone, aggregated into one operating system. This table summarizes briefly the entire results of the investigation; it does not include wage saving.

TABLE 43.—*Comparison of steam and electric operation for all selected divisions (combined).*

	Freight.		Passenger.		Switcher.		All services.	
	Unit value.	Total.	Unit value.	Total.	Unit value.	Total.	Unit value.	Total.
Miles of road operated	....	6,395	....	6,395	....	....	....	6,395
Miles of track	....	11,296	....	11,296	....	7,831	....	19,127
Steam.								
Average number of assigned locomotives	....	2,927	....	1,620	....	1,995	....	6,542
Weight on drivers. tons	97	283,171	65	104,655	74	147,058	82	534,884
Locomotive-miles, thousands	....	58,517	....	54,946	....	42,882	....	156,345
Trailing ton-miles, millions	....	723,896	....	....	....	....	....	....
Car-miles...thousands	....	....	....	....	....	....	....	....
Coal burned......tons	....	7,424,500	....	3,450,400	....	2,438,600	....	13,313,500
Coal per locomotive-mile........pounds	....	254	....	126	....	114	....	170
Electric.								
Kilowatt-hours (thousand-ton-mile basis) thousands	36.8	2,666,400	....	....	....	....	....	....
Kilowatt-hours (locomotive-mile basis) thousands	45.6	2,666,400	20.6	1,133,000	14.6	623,900	28.3	4,423,300
Equivalent coal, pounds and tons	2.0	2,666,400	2.0	1,133,000	2.0	623,900	2.0	4,423,300
Coal saved, per cent and tons	64.1	4,758,100	67.2	2,317,400	74.4	1,814,700	66.8	8,890,200
Unit and total cost.								
Cost of coal and water	$5.17	$38,350,800	....	$17,822,800	....	$12,596,600	$5.17	$68,770,200
Cost of electric energy	.01	26,664,000	....	11,330,000	....	6,239,000	....	44,233,000
Excess cost of steam	....	11,686,800	....	6,492,800	....	6,357,600	....	24,537,200
Locomotive maintenance, steam[a]	.49	28,649,500	$0.396	21,766,900	$0.376	16,121,200	.426	66,537,600
Locomotive maintenance, electric[a]	.0826	4,831,800	....	4,537,000	....	3,540,800	.0826	12,909,600
Maintenance of distribution system	600.00	3,545,800	....	3,325,900	400.00	3,132,400	....	10,004,100
Substation operation and maintenance	.0007	1,866,600	....	793,100	....	436,800	.0007	3,096,500
Total cost, steam operation	....	67,000,300	....	39,589,700	....	28,717,800	....	135,307,800
Total cost, electric operation	....	36,908,200	....	19,986,000	....	13,349,000	....	70,243,200
Excess cost, steam operation	2,664.00	30,092,100	1,735.00	19,603,700	1,963.00	15,368,800	3,402.00	65,064,600

[a] Includes engine-house expense.

Figure 16 shows the growth of traffic, both freight and passenger, of track, and of tractive power for the class 1 railroads in the superpower zone from 1900 to 1919. The annual rate of growth has been 5.3 per cent in passenger-miles, 4.5 per cent in ton-miles, 0.75 per cent in all track, and 6.6 per cent in tractive power of locomotives.

The amount of money required for electrification is indicated in Table 42 as $570,000,000. This figure is based on costs prevailing in 1919, but at present costs (June, 1921) it would be reduced by 18 per cent, to approximately $467,000,000, and before this construction can be undertaken there will be further material reductions. Probably five years from now the entire work outlined could be done for not more than $400,000,000. This is comparatively a moderate sum. Good railroad authorities have stated repeatedly that more than $1,000,000,000 a year is needed by the railroads of the United States for extensions and betterments. The part of this total to be allocated to the superpower zone, as determined by the number of locomotives, would be $150,000,000. The amount required for normal extensions and betterments for three years would therefore be sufficient to electrify the 30 selected divisions of the railroads in this territory, with an annual saving of more than 14 per cent. The most valuable feature of the change, however, is not the amount saved but the great increase in maximum capacity of existing trackage and the general advantages of electric operation.

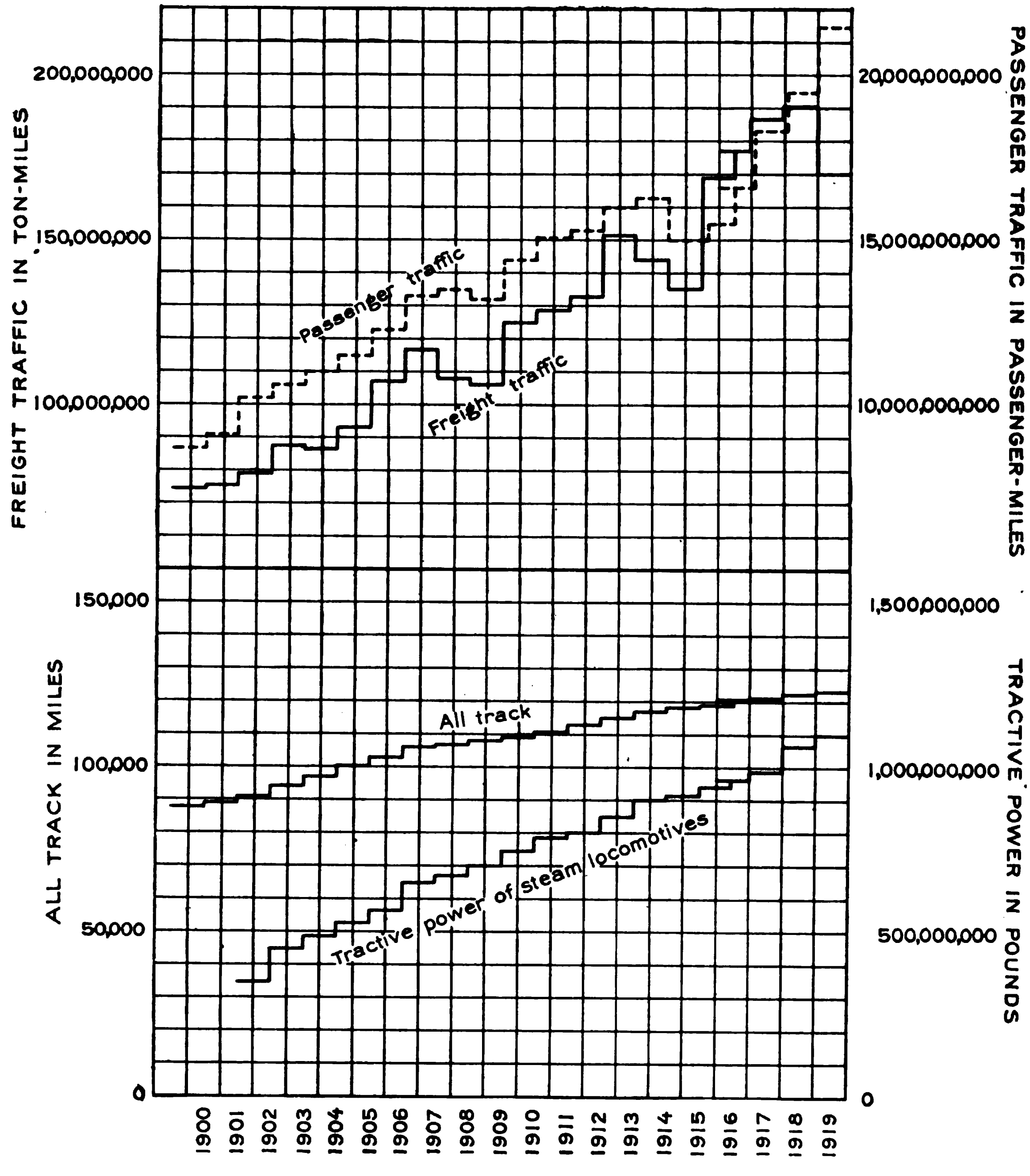


FIGURE 16.—Growth of steam railroads in the superpower zone in 1900-1919. Annual rate of growth compounded, 1900-1918: Passenger-miles, 5.3 per cent; ton-miles, 4.5 per cent; all track, 0.75 per cent; tractive power, 6.6 per cent.

These figures indicate that with a return of normal financial conditions all these lines should be electrified before further great expenditures have been incurred to increase in a minor degree the capacity of the existing tracks and yards. Steam operation can not satisfactorily meet the conditions of the crowded terminal herein described as the superpower zone; electric operation can easily do it.

APPENDIX D.

INDUSTRY IN THE SUPERPOWER ZONE.

By H. W. Butler, H. Goodwin, Jr., and others of the engineering staff.

CONCLUSIONS.

A survey of the industrial establishments in the superpower zone in 1919 shows that the maximum economical use of purchased power in that year would have saved 13,502,100 tons of coal. This estimate assumes a consumption equivalent to 2 pounds of coal per kilowatt-hour at the motor leads in the industrial establishments. In order to save this coal, however, the industries would have had to purchase 5,623,800,000 kilowatt-hours more than they did.

The energy developed by prime movers in the industries was equivalent to 9,311,440,000 kilowatt-hours. The energy purchased from central electric stations to supply electric motors in the industries was 3,338,800,000 kilowatt-hours.

INDUSTRIES CONSIDERED.

"Industries" as used in this report means privately owned manufacturing establishments, laundries, mines and quarries, and Government institutions. The establishments considered include only those whose annual product has a value greater than $500. Table 48 gives the statistics for 53 industries, which have been arranged in 17 major groups adopted by the Bureau of the Census, to permit convenient comparison of the information here given with other information gathered by the Census Bureau regarding these industries.

FUNDAMENTAL INFORMATION RECEIVED FROM BUREAU OF THE CENSUS.

THE TABLES IN GENERAL.

The only source of general figures showing power and fuel used proved to be the Bureau of the Census. The census of manufactures covering the calendar year 1919 was in process of compilation, and the Census Bureau arranged to cooperate with the superpower survey by supplying advance information in special tabular form for analysis. The titles of the tables follow:

Table 44.—Mechanical power-supply equipment and fuel used by all industries, by size of plant.

Table 45.—Mechanical power-supply equipment and fuel used by all industries, by character of power supply.

Table 46.—Mechanical power-supply equipment and fuel used by all industries, by industry subgroups and character of power supply.

Table 47.—Mechanical power-supply equipment and fuel used by all industries, by counties and size of plant.

Table 48.—Summary and analysis of industrial power and fuel, by industry groups. (The summary consists of Census data; the analysis was made by the superpower survey.)

The column headings are practically the same in all tables. They follow the Census standard headings except as noted.

"Power-supply equipment" is used instead of the old Census term "primary power."

"Prime movers" is used instead of "owned" power.

"Operated by purchased energy" is used instead of "rented" power.

"Aggregate horsepower" of "power-supply equipment" (column 6) is the sum of the "total horsepower" of "prime movers" (column 7) and the "total horsepower" "operated by purchased energy" (column 16).

"Total horsepower" of "prime movers" (column 7) is the sum of columns 9, 11, 13, and 15. Prime movers are included whether they are directly connected to machinery, such as pumps, air compressors, or electrical generators, or used to drive shafting. Boiler-room and engine-room auxiliaries are not included.

"Internal-combustion engines" (columns 12 and 13) include gas, gasoline, and oil engines, whether run on special fuel or waste gases.

"Water wheels" (columns 14 and 15) include hydraulic turbines and an insignificant number of small water motors run from city water mains.

"Electric motors" "operated by purchased energy" (columns 17 and 18) consist chiefly of motors operated from the circuits of central stations but include also some that are operated by energy purchased from isolated plants.

"Other horsepower" "operated by purchased energy" (column 19) is chiefly power received through belting or shafting from the power plant of some other industrial establishment.

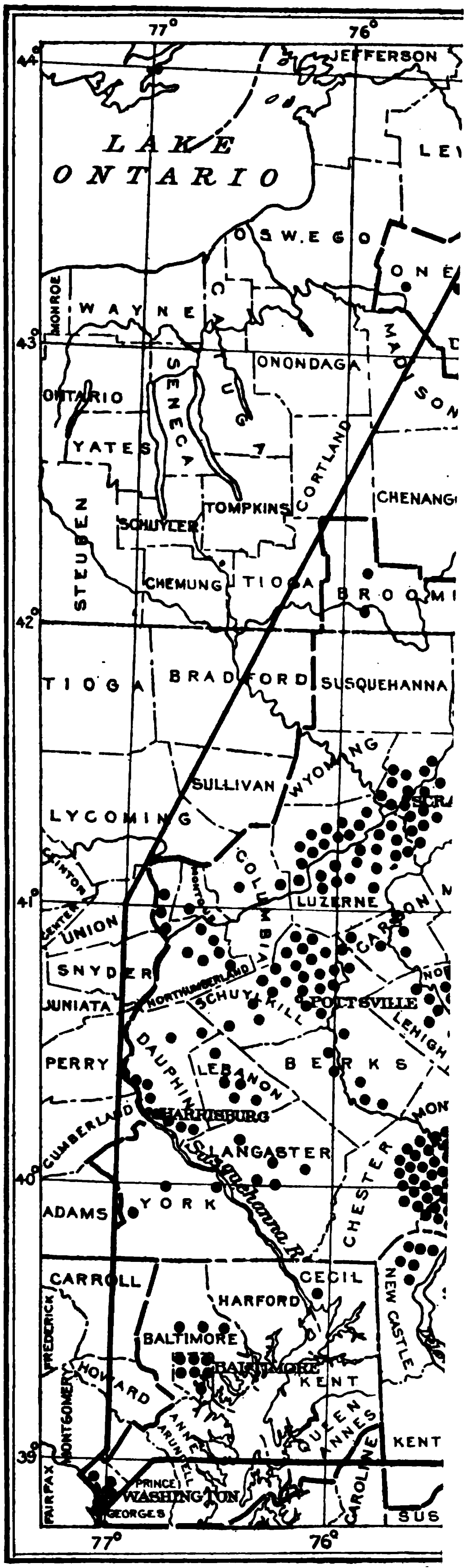
"Total number" of "electric motors" (column 20) is the sum of those "operated by purchased energy" (column 17) and those "run by current generated in establishment" (column 22). Similarly "Total horsepower" (column 21) is the sum of columns 18 and 23. A comparison of column 21 with column 6 gives an idea of the application of electricity in any industry.

"Fuel used" is expressed in "long tons" (2,240 pounds) for anthracite and "short tons" (2,000 pounds) for bituminous coal and coke. Column 26 ("Total equivalent bituminous coal") is derived from columns 24 and 25 and is presented to permit a comparison of items that show various proportions of anthracite and bituminous coal. A careful investigation of the quality of coal used by the industries showed that one long ton of anthracite was equivalent, on the average, to about nine-tenths of a short ton of bituminous coal in producing power. The "total equivalent bituminous coal" is therefore determined by multiplying the "anthracite" tons by 0.9 and adding the result to the "bituminous" tons. As comparatively little coke is used for producing power in the superpower zone, this item is not included in the "total equivalent bituminous coal."

Statistics on the use of oil and manufactured gas in the industries are also compiled by the Bureau of the Census, but the data for 1919 were not ready in time for use. The amount of oil used for producing power is very small in comparison with the amount of coal used, and as the oil reserves are scant it must remain small.

LIMITATIONS OF STATISTICS.

It is difficult to show the present complicated conditions in industry, with its interrelated power and fuel supply, in a few uniform tables. The totals given are undoubtedly very accurate, but as the divisions become finer and finer they must be used with increasing care and knowledge of the rules used in compilation. For instance: (*a*) Many plants, particularly the larger ones, that are normally operated by water power have complete steam plants in reserve for their operation during periods of low water. Both forms of power are reported, and in a small group either may apparently show a disproportionately large amount of power. (*b*) Some plants have discontinued regular operation of direct prime movers and purchase power from a central station but must also report the old prime movers held in reserve. This again leads to a duplication. (*c*) Other plants are electrically driven throughout and purchase power part of the time and generate it another part. At some times the central station connection is only "reserve," and at other times the prime movers are only "reserve," so that to avoid duplication and to make the total as nearly correct as possible, it is necessary to report the motors as "run by current generated in establishment reporting." If the prime movers are used only occasionally, the report obviously does not give the central station any credit for what it supplies. (*d*) Still other plants abandoned the use of prime movers near the end of 1919 and purchased all energy. Thus the statistics show that the motors were operated by purchased energy on December 31, 1919, but that the fuel used during the year was almost enough to operate a steam plant instead of the small amount that might be needed with purchased power. This condition happened to be particularly true of ice plants, many of which changed to central-station service in 1919.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CHENANGO
STEUBEN
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TOMPKINS
CHEMUNG
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BROOME
TIOGA
BRADFORD
SUSQUEHANNA
WYOMING
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CARBON
SNYDER
NORTHUMBERLAND
JUNIATA
SCHUYLKILL
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NOR
PERRY
DAUPHIN
LEBANON
BERKS
MON
CUMBERLAND
HARRISBURG
LANCASTER
CHESTER
ADAMS
YORK
Susquehanna R.
CARROLL
HARFORD
CECIL
NEW CASTLE
FREDERICK
BALTIMORE
BALTIMORE
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THE TABLES IN DETAIL.

Table 44 shows the total mechanical power-supply equipment and fuel used by all industries in the zone, by size of plant. First is shown the fuel used by establishments reporting "no power." On the following lines are given the power and fuel used by establishments reporting an aggregate of 1 to 200 horsepower, 201 to 500 horsepower, and 501 horsepower or more. The average size is interesting. The figures for the larger plants indicate that 2,732 establishments use 6,689,751 horsepower—that is, 3.6 per cent of the establishments reporting power are larger than 500 horsepower and use 73.8 per cent of the grand total horsepower.

Table 45 shows the total mechanical power-supply equipment and fuel, by character of power supply, with each group subdivided by size of plant. This subdivision is made particularly for analysis. Therefore two clear-cut groups have been selected—establishments reporting "steam power only" and establishments reporting "purchased electric power only." The ratio of fuel used to power is in these establishments obviously simple, and the amount of coal used per horsepower has a definite significance. All combinations of steam power with purchased power and all other forms of power exhibit more complicated relations and have been thrown together under the heading "All other power." The relations in this group may usually be analyzed by means of the factors derived from the previous groups by making proper allowance for the considerations noted above under "Limitations of statistics."

Table 46 presents data for each industrial subgroup similar to those presented for all industries in Table 45. The totals of each group in Table 46 are carried forward to Table 48. Remarks in regard to Table 45 apply to Table 46 with additional force. This table shows clearly for each group of industries the character of power supply and the fuel used, from which can be determined the relation of fuel used to character of power supply.

Table 47 gives the mechanical power-supply equipment reported in each county, by size of plant, as explained for Table 44. This table is of interest as showing the distribution of plants of various sizes and the extent to which electric power is purchased in different counties.

Plate VII shows the distribution by counties of isolated-plant power, each dot representing 10,000 horsepower of steam, oil, or gasoline engines.

TABLE 44.—*Mechanical power-supply equipment and*

[Data from census of

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments. Number.	Establishments. Average size (horsepower).	Power-supply equipment. Aggregate horsepower.	Prime movers. Total horsepower.	Steam engines. Number.	Steam engines. Horsepower.	Steam turbines. Number.	Steam turbines. Horsepower.	Internal-combustion engines. Number.	Internal-combustion engines. Horsepower.	Water wheels. Number.	Water wheels. Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Grand total, all industries.	No power		19,757	....	....	....	....	....	....	....	....	....	....	....
	All power:													
		1-200	70,654	21	1,485,664	692,047	11,022	535,505	276	10,135	5,511	73,408	2,333	72,999
		201-500	2,841	315	894,056	569,154	4,618	488,880	174	19,514	294	11,662	627	49,098
		501 and above	2,732	2,450	6,689,751	4,985,801	17,739	3,231,483	1,665	1,141,412	441	193,970	1,748	418,936
		Total power	76,227	119	9,069,471	6,247,002	33,379	4,255,868	2,115	1,171,061	6,246	279,040	4,708	541,033
		Grand total	95,984	....	9,069,471	6,247,002	33,379	4,255,868	2,115	1,171,061	6,246	279,040	4,708	541,033

TABLE 45.—*Mechanical power-supply equipment and*

[Data from census of

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments. Number.	Establishments. Average size (horsepower).	Power-supply equipment. Aggregate horsepower.	Prime movers. Total horsepower.	Steam engines. Number.	Steam engines. Horsepower.	Steam turbines. Number.	Steam turbines. Horsepower.	Internal-combustion engines. Number.	Internal-combustion engines. Horsepower.	Water wheels. Number.	Water wheels. Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Grand total, all industries.	No power		19,757	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:													
		1-200	6,446	61	395,029	395,029	7,886	388,054	174	6,975	....	....	....	....
		201-500	949	322	305,909	305,909	2,380	291,745	118	14,164	....	....	....	....
		501 and above	912	2,210	2,017,858	2,017,858	7,357	1,437,942	790	579,916	....	....	....	....
			8,307	327	2,718,796	2,718,796	17,623	2,117,741	1,082	601,055	....	....	....	....
	Purchased electric power only:													
		1-200	53,968	13	680,456	....	....	....	....	....	....	....	....	....
		201-500	681	303	206,611	....	....	....	....	....	....	....	....	....
		501 and above	367	1,620	596,240	....	....	....	....	....	....	....	....	....
			55,016	27	1,483,307	....	....	....	....	....	....	....	....	....
	All other power:													
		1-200	10,240	40	410,179	297,018	3,136	147,451	102	3,160	5,511	73,408	2,333	72,999
		201-500	1,211	314	381,536	263,245	2,238	197,135	56	5,350	294	11,662	627	49,098
		501 and above	1,453	2,800	4,075,653	2,967,943	10,382	1,793,541	875	561,496	441	193,970	1,748	418,936
			12,904	377	4,867,368	3,528,206	15,756	2,138,127	1,033	570,006	6,246	279,040	4,708	541,033
		Total power	76,227	119	9,069,471	6,247,002	33,379	4,255,868	2,115	1,171,061	6,246	279,040	4,708	541,033
		Grand total	95,984	....	9,069,471	6,247,002	33,379	4,255,868	2,115	1,171,061	6,246	279,040	4,708	541,033

fuel used by all industries, by size of plant.

manufactures, 1919.]

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
....	....	....	....	....	....	....	....	234,010	381,727	591,884	25,860
793,617	208,962	763,163	30,454	221,738	837,261	12,776	74,098	2,528,361	3,887,872	6,158,375	566,778
324,902	35,593	321,592	3,310	58,228	481,523	22,635	159,931	1,265,149	3,899,249	5,037,683	308,288
1,703,950	117,406	1,685,960	17,990	280,941	4,017,843	163,535	2,331,883	16,882,346	26,498,476	41,675,571	4,760,102
2,822,469	361,961	2,770,715	51,754	560,907	5,336,627	198,946	2,565,912	20,675,855	34,287,597	52,871,629	5,635,168
2,822,469	361,961	2,770,715	51,754	560,907	5,336,627	198,946	2,565,912	20,909,865	34,669,324	53,463,513	5,661,028

fuel used by all industries, by character of power supply.

manufactures, 1919.]

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
....	....	....	....	....	....	....	....	234, 010	381, 727	591, 884	25, 860
....	....	....	....	8, 633	52, 326	8, 633	52, 326	855, 337	1, 886, 507	2, 655, 485	149, 745
....	....	....	....	17, 179	115, 860	17, 179	115, 860	657, 603	1, 889, 242	2, 480, 059	131, 501
....	....	....	....	88, 382	1, 143, 666	88, 382	1, 143, 666	7, 070, 078	12, 139, 926	18, 500, 448	2, 286, 003
....	....	....	....	114, 194	1, 311, 852	114, 194	1, 311, 852	8, 583, 018	15, 915, 675	23, 635, 992	2, 567, 249
680, 456	196, 275	680, 456	....	196, 275	680, 456	....	....	1, 091, 594	965, 127	1, 943, 805	338, 435
206, 611	23, 709	206, 611	....	23, 709	206, 611	....	....	123, 109	575, 813	685, 748	44, 734
596, 240	38, 790	596, 240	....	38, 790	596, 240	....	....	197, 520	2, 542, 126	2, 719, 861	100, 182
1, 483, 307	258, 774	1, 483, 307	....	258, 774	1, 483, 307	....	....	1, 412, 223	4, 083, 066	5, 349, 414	483, 351
113, 161	12, 687	82, 707	30, 454	16, 830	104, 479	4, 143	21, 772	581, 430	1, 036, 238	1, 559, 085	78, 598
118, 291	11, 884	114, 981	3, 310	17, 340	159, 052	5, 456	44, 071	484, 437	1, 436, 194	1, 871, 876	132, 053
1, 107, 710	78, 616	1, 089, 720	17, 990	153, 769	2, 277, 937	75, 153	1, 188, 217	9, 614, 748	11, 816, 424	20, 455, 262	2, 373, 917
1, 339, 162	103, 187	1, 287, 408	51, 754	187, 939	2, 541, 468	84, 752	1, 254, 060	10, 680, 615	14, 288, 856	23, 886, 223	2, 584, 568
2, 822, 469	361, 961	2, 770, 715	51, 754	560, 907	5, 336, 627	198, 946	2, 565, 912	20, 675, 855	34, 287, 597	52, 871, 629	5, 635, 168
2, 822, 469	361, 961	2, 770, 715	51, 754	560, 907	5, 336, 627	198, 946	2, 565, 912	20, 909, 865	34, 669, 324	53, 463, 513	5, 661, 028

TABLE 46.—*Mechanical power-supply equipment and fuel*

[Data from census of

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
			Number.	Average size (horsepower).	Aggregate horsepower.	Prime movers.								
						Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1a. Slaughtering.	No power		171	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	68	48	3,191	3,191	92	3,129	3	62	....	....	....	....
		201-500	14	330	4,682	4,682	52	4,682	0	0	....	....	....	....
		501 and above	14	1,020	14,270	14,270	72	13,173	9	1,097	....	....	....	....
			96	230	22,143	22,143	216	20,984	12	1,159	....	....	....	....
	Purchased electric power only:	1-200	343	21	7,228	....	....	....	....	....	....	....	....	....
		201-500	5	281	1,406	....	....	....	....	....	....	....	....	....
			348	25	8,634	....	....	....	....	....	....	....	....	....
	All other power:	1-200	87	32	2,755	1,626	53	1,546	3	80	0	0	0	0
		201-500	14	295	4,114	2,158	32	2,013	2	145	0	0	0	0
		501 and above	7	1,808	12,654	7,423	31	5,830	8	1,593	0	0	0	0
			108	1,800	19,523	11,207	116	9,389	13	1,818	0	0	0	0
		Total power	552	91	50,300	33,350	332	30,373	25	2,977	0	0	0	0
		Grand total	723	....	50,300	33,350	332	30,373	25	2,977	0	0	0	0
1b. Flour-mill and grist-mill products.	No power		4	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	111	5	6,430	6,430	108	6,315	3	115	....	....	....	....
		201-500	1	225	225	225	1	225	0	0	....	....	....	....
		501 and above	2	700	1,400	1,400	5	1,400	0	0	....	....	....	....
			114	70	8,055	8,055	114	7,940	3	115	....	....	....	....
	Purchased electric power only:	1-200	245	38	9,431	....	....	....	....	....	....	....	....	....
		201-500	2	362	725	....	....	....	....	....	....	....	....	....
			247	41	10,156	....	....	....	....	....	....	....	....	....
	All other power:	1-200	847	43	36 351	34,498	57	2,865	1	50	239	5,431	1,017	26,152
		201-500	7	310	2,173	1,705	1	150	0	0	1	40	14	1,515
		501 and above	2	690	1,380	1,330	3	650	0	0	0	0	14	680
			856	47	39,904	37,533	61	3,665	1	50	240	5,471	1,045	28,347
		Total power	1,217	48	58,115	45,588	175	11,605	4	165	240	5,471	1,045	28,347
		Grand total	1,221	....	58,115	45,588	175	11,605	4	165	240	5,471	1,045	28,347
1c. Bread and bakery products.	No power		2,949	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	22	51	1,118	1,118	24	1,043	1	75	....	....	....	....
		201-500	11	362	3,987	3,987	29	3,987	0	0	....	....	....	....
		501 and above	6	1,473	8,839	8,839	28	6,839	6	2,000	....	....	....	....
			39	356	13,944	13,944	81	11,869	7	2,075	....	....	....	....
	Purchased electric power only:	1-200	5,357	6	30,693	....	....	....	....	....	....	....	....	....
		201-500	9	264	2,375	....	....	....	....	....	....	....	....	....
		501 and above	2	940	1,881	....	....	....	....	....	....	....	....	....
			5,368	6	34,949	....	....	....	....	....	....	....	....	....
	All other power:	1-200	182	23	4,190	2,535	40	1,507	3	11	139	995	8	22
		201-500	6	264	1,582	1,047	14	1,047	0	0	0	0	0	0
		501 and above	3	2,570	7,712	1,030	5	630	1	400	0	0	0	0
			191	70	13,484	4,612	59	3,184	4	411	139	995	8	22
		Total power	5,598	11	62,377	18,556	140	15,053	11	2,486	139	995	8	22
		Grand total	8,547	....	62,377	18,556	140	15,053	11	2,486	139	995	8	22

used by industry subgroups, by character of power supply.

manufactures, 1919.]

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
....	....	....	....	....	....	....	....	467	548	978	0
....	....	....	....	81	703	81	703	14,496	16,339	29,389	47
....	....	....	....	202	2,284	202	2,284	15,131	38,365	51,965	0
....	....	....	....	574	6,608	574	6,608	81,593	97,844	171,344	7,358
....	....	....	....	857	9,595	857	9,595	111,220	152,548	252,698	7,405
7,228	865	7,228	....	865	7,228	....	....	4,372	7,380	11,310	126
1,406	96	1,406	....	96	1,406	....	....	96	2,398	2,485	0
8,634	961	8,634	....	961	8,634	....	....	4,468	9,778	13,795	126
1,129	93	967	142	98	1,001	5	14	5,333	12,375	17,175	106
1,956	187	1,956	0	227	2,303	40	347	14,049	14,656	27,256	....
5,231	447	5,231	0	561	6,517	114	1,286	89,131	26,949	106,949	....
8,316	727	8,174	142	886	9,821	159	1,647	108,513	53,980	151,380	106
16,950	1,688	16,808	142	2,704	28,050	1,016	11,242	224,201	216,306	417,873	7,637
16,950	1,688	16,808	142	2,704	28,050	1,016	11,242	224,668	216,854	418,851	7,637
....	....	....	....	....	....	....	....	0	0	0	0
....	....	....	....	2	11	2	11	8,896	10,155	18,145	0
....	....	....	....	0	0	0	0	0	1,050	1,050	0
....	....	....	....	13	128	13	128	7,500	4,080	10,830	0
....	....	....	....	15	139	15	139	16,396	15,285	30,025	0
9,431	710	9,431	....	710	9,431	....	....	670	602	1,205	4
725	31	725	....	31	725	....	....	0	0	0	0
10,156	741	10,156	....	741	10,156	....	....	670	602	1,205	4
1,853	107	1,775	78	123	1,996	16	221	7,988	3,993	11,173	8[illegible]
468	40	468	0	79	968	39	500	49	870	914	[illegible]
50	1	50	0	1	50	0	0	0	362	363	[illegible]
2,371	148	2,293	78	203	3,014	55	721	8,037	5,225	12,450	8[illegible]
12,527	889	12,449	78	959	13,309	70	860	25,103	21,112	43,680	81
12,527	889	12,449	78	959	13,309	70	860	25,103	21,112	43,680	81
....	....	....	....	....	....	....	....	90,662	8,137	89,637	16.511
....	....	....	....	50	355	50	355	2,335	13,040	15,140	[illegible]
....	....	....	....	353	2,560	353	2,560	18,634	14,540	31,340	3,775
....	....	....	....	1,035	5,812	1,035	5,812	43,280	13,268	52,268	9[illegible]8
....	....	....	....	1,438	8,727	1,438	8,727	64,249	40,848	98,748	4,741
30,693	10,296	30,693	....	10,296	30,693	....	....	261,464	38,469	273,469	5[illegible],984
2,375	425	2,375	....	425	2,375	....	....	8,086	2,077	9,337	1,168
1,881	317	1,881	....	317	1,881	....	....	5,715	473	5,623	0
34,949	11,038	34,949	....	11,038	34,949	....	....	275,265	41,019	288,429	52,152
1,655	346	1,638	17	457	2,113	111	475	17,028	10,580	25,880	1,699
535	74	535	0	124	844	50	309	12,082	5,206	16,106	0
6,682	277	6,682	0	414	7,329	137	647	13,565	8,320	20,520	1,858
8,872	697	8,855	17	995	10,286	298	1,431	42,675	24,105	62,505	3,557
43,821	11,735	43,804	17	13,471	53,962	1,736	10,158	382,189	105,972	449,682	60,452
43,821	11,735	43,804	17	13,471	53,962	1,736	10,158	472,851	114,109	539,319	76,963

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
			Number.	Average size (horsepower).	Aggregate horsepower.	Prime movers.								
						Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1d. Sugar refining.	Steam power only:	501 and above	13	2,700	35,041	35,041	229	23,678	22	11,363	....	....	....	....
		Total power	13	2,700	35,041	35,041	229	23,678	22	11,363	....	....	....	....
1e. All other food products.	No power		806	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	687	32	21,836	21,836	854	21,611	19	225	....	....	....	....
		201-500	31	328	10,211	10,211	93	10,101	3	110	....	....	....	....
		501 and above	15	906	13,638	13,638	73	12,828	4	810	....	....	....	....
			733	62	45,685	45,685	1,020	44,540	26	1,145	....	....	....	....
	Purchased electric power only:	1-200	2,474	15	36,219	....	....	....	....	....	....	....	....	....
		201-500	40	299	11,947	....	....	....	....	....	....	....	....	....
		501 and above	7	804	5,631	....	....	....	....	....	....	....	....	....
			2,521	21	53,797	....	....	....	....	....	....	....	....	....
	All other power:	1-200	765	30	23,305	17,412	275	9,552	10	276	602	6,108	66	1,476
		201-500	36	300	10,831	6,281	84	5,135	3	226	17	670	1	250
		501 and above	30	1,524	45,733	30,171	110	26,306	11	990	31	2,548	15	327
			831	96	79,869	53,864	469	40,993	24	1,492	640	9,326	82	2,053
		Total power	4,085	44	179,351	99,549	1,489	85,533	50	2,637	640	9,326	82	2,053
		Grand total	4,891	....	179,351	99,549	1,489	85,533	50	2,637	640	9,326	82	2,053
2a. Cotton goods, small wares, and lace.	No power		13	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	48	123	5,937	5,937	61	5,937	0	0	....	....	....	....
		201-500	22	345	7,593	7,593	38	7,493	1	100	....	....	....	....
		501 and above	72	2,395	172,596	172,596	162	145,539	28	27,057	....	....	....	....
			142	1,310	186,126	186,126	261	158,969	29	27,157	....	....	....	....
	Purchased electric power only:	1-200	193	51	9,839	....	....	....	....	....	....	....	....	....
		201-500	14	320	4,506	....	....	....	....	....	....	....	....	....
		501 and above	19	2,760	52,579	....	....	....	....	....	....	....	....	....
			226	295	66,924	....	....	....	....	....	....	....	....	....
	All other power:	1-200	95	57	5,436	3,630	23	1,411	0	0	22	509	31	1,710
		201-500	30	347	10,425	9,386	36	5,405	0	0	0	0	39	3,981
		501 and above	183	3,420	626,602	514,737	452	252,998	92	124,393	10	1,465	592	135,881
			308	2,080	642,463	527,753	511	259,814	92	124,393	32	1,974	662	141,572
		Total power	676	1,320	895,513	713,879	772	418,783	121	151,550	32	1,974	662	141,572
		Grand total	689	....	895,513	713,879	772	418,783	121	151,550	32	1,974	662	141,573
2b. Knit goods.	No power		61	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	129	74	9,552	9,552	140	9,301	5	251	....	....	....	....
		201-500	12	308	3,696	3,696	18	3,696	0	0	....	....	....	....
		501 and above	6	1,197	7,183	7,183	13	3,515	5	3,668	....	....	....	....
			147	139	20,431	20,431	171	16,512	10	3,919	....	....	....	....
	Purchased electric power only:	1-200	949	15	14,401	....	....	....	....	....	....	....	....	....
		201-500	9	278	2,497	....	....	....	....	....	....	....	....	....
		501 and above	4	1,071	4,285	....	....	....	....	....	....	....	....	....
			962	22	21,183	....	....	....	....	....	....	....	....	....
	All other power:	1-200	152	49	7,450	4,765	68	3,336	1	35	24	235	33	1,159
		201-500	40	310	12,394	8,535	40	6,275	2	110	0	0	30	2,150
		501 and above	21	1,330	27,981	19,671	52	13,672	2	1,750	0	0	28	4,249
			213	224	47,825	32,971	160	23,283	5	1,895	24	235	91	7,558
		Total power	1,322	68	89,439	53,402	331	39,795	15	5,814	24	235	91	7,558
		Grand total	1,383	....	89,439	53,402	331	39,795	15	5,814	24	235	91	7,558

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).								
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.	Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
16	17	18	19	20	21	22	23	24	25	26	27
....	....	....	....	2,582	37,090	2,582	37,090	406,248	865,118	1,231,118	180
....	....	....	....	2,582	37,090	2,582	37,090	406,248	865,118	1,231,118	180
....	....	....	....	....	....	....	....	4,330	12,777	16,674	431
....	....	....	....	493	2,558	493	2,558	40,226	104,951	141,158	281
....	....	....	....	562	3,371	562	3,371	14,988	42,175	55,675	991
....	....	....	....	1,547	11,893	1,547	11,893	67,331	22,864	83,461	420
....	....	....	....	2,602	17,822	2,602	17,822	122,545	169,990	280,294	1,692
3,6219	7,910	36,219	....	7,910	36,219	....	....	43,464	50,252	89,365	1,739
11,947	1,420	11,947	....	1,420	11,947	....	....	9,553	19,746	28,345	1,457
5,631	708	5,631	....	708	5,631	....	....	1,914	4,957	6,679	0
53,797	10,038	53,797	....	10,038	53,797	....	....	54,931	74,955	124,389	3,196
5,893	1,138	5,387	506	1,228	6,014	90	627	23,631	61,596	82,854	115
4,550	515	4,190	360	802	5,482	287	1,292	12,957	41,334	53,000	16
15,562	1,812	15,562	0	3,457	31,487	1,645	15,925	168,572	124,850	276,563	64
26,005	3,465	25,139	866	5,487	42,983	2,022	17,844	205,150	227,780	412,417	195
79,802	13,503	78,936	866	18,127	114,602	4,624	35,666	382,626	472,725	817,100	5,083
79,802	13,503	78,936	866	18,127	114,602	4,624	35,666	386,956	485,502	833,774	5,514
....	....	....	....	....	....	....	....	0	1,648	1,648	0
....	....	....	....	133	787	133	787	14,355	23,777	36,377	350
....	....	....	....	181	1,749	181	1,749	7,732	28,036	34,996	0
....	....	....	....	3,347	46,366	3,347	46,366	99,563	410,178	499,678	13,982
....	....	....	....	3,661	48,902	8,661	48,902	121,650	461,991	571,351	14,332
9,839	2,227	9,839	....	2,227	9,839	....	....	3,901	12,108	15,608	399
4,506	865	4,506	....	865	4,506	....	....	1,794	7,163	8,783	0
52,579	3,629	52,579	....	3,629	52,579	....	....	4,891	14,501	18,901	0
66,924	6,721	66,924	....	6,721	66,924	....	....	10,586	33,772	43,292	399
1,806	75	723	1,083	99	898	24	175	2,178	14,601	16,551	1
1,039	67	1,039	0	236	2,256	169	1,217	7,305	33,930	40,501	0
111,865	10,250	111,470	395	20,259	267,788	10,009	156,318	166,061	1,137,722	1,278,722	1,694
114,710	10,392	113,232	1,478	20,594	270,942	10,202	157,710	175,544	1,186,253	1,335,774	1,695
181,634	17,113	180,156	1,478	30,976	386,768	13,863	206,612	307,780	1,682,016	1,950,417	16,426
181,634	17,113	180,156	1,478	30,976	386,768	13,863	206,612	307,780	1,683,664	1,952,065	16,426
....	....	....	....	....	....	....	....	193	201	374	0
....	....	....	....	642	2,937	642	2,937	22,773	42,714	63,114	43
....	....	....	....	555	1,576	555	1,576	10,163	10,446	19,546	0
....	....	....	....	814	4,747	814	4,747	17,694	20,390	36,290	74
....	....	....	....	2,011	9,260	2,011	9,260	50,630	73,550	118,950	117
14,401	3,885	14,401	....	3,885	14,401	....	....	16,698	40,666	55,666	41
2,497	526	2,497	....	526	2,497	....	....	900	2,892	3,702	0
4,285	338	4,285	....	338	4,285	....	....	0	7,696	7,696	0
21,183	4,749	21,183	....	4,749	21,183	....	....	17,598	51,254	67,064	41
2,685	337	1,422	1,263	496	2,346	159	924	6,024	19,743	25,143	0
3,859	274	3,084	775	413	4,665	139	1,581	9,034	44,448	52,548	0
8,310	820	8,310	0	1,094	11,544	274	3,234	5,522	83,973	88,933	0
14,854	1,431	12,816	2,038	2,003	18,555	572	5,739	20,580	166,624	166,624	0
36,037	6,180	33,999	2,038	8,763	48,998	2,583	14,999	88,808	272,968	352,636	158
36,037	6,180	33,999	2,038	8,763	48,998	2,583	14,999	89,001	273,169	353,012	158

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
			Number.	Average size (horsepower).	Aggregate horsepower.	Prime movers.								
						Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2c. Silk goods.	No power		32	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	82	111	9,069	9,069	95	8,719	3	350	....	....	....	....
		201-500	41	298	12,273	12,273	55	11,068	9	1,205	....	....	....	....
		501 and above	11	1,280	14,131	14,131	35	7,781	10	6,350	....	....	....	....
			134	264	35,473	35,473	185	27,568	22	7,905	....	....	....	....
	Purchased electric power only:	1-200	687	30	20,908	....	....	....	....	....	....	....	....	....
		201-500	25	270	6,749	....	....	....	....	....	....	....	....	....
		501 and above	7	749	5,243	....	....	....	....	....	....	....	....	....
			719	46	32,900	....	....	....	....	....	....	....	....	....
	All other power:	1-200	247	38	9,371	4,771	49	3,318	2	87	37	680	16	686
		201-500	26	315	8,210	5,731	40	5,394	0	0	1	12	2	325
		501 and above	32	1,655	53,107	34,077	105	23,491	10	4,167	3	635	38	5,784
			305	232	70,688	44,579	194	32,203	12	4,254	41	1,327	56	6,795
	Total power		1,158	120	139,061	80,052	379	59,771	34	12,159	41	1,327	56	6,795
	Grand total		1,190	....	139,061	80,052	379	59,771	34	12,159	41	1,327	56	6,795
2d. All woolen goods.	No power		13	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	72	130	9,445	9,445	77	9,210	2	235	....	....	....	....
		201-500	40	333	13,331	13,331	59	12,781	2	550	....	....	....	....
		501 and above	42	2,030	85,531	85,531	96	52,147	30	33,384	....	....	....	....
			154	700	108,307	108,307	232	74,138	34	34,169	....	....	....	....
	Purchased electric power only:	1-200	82	85	6,989	....	....	....	....	....	....	....	....	....
		201-500	24	319	7,663	....	....	....	....	....	....	....	....	....
		501 and above	8	1,434	11,474	....	....	....	....	....	....	....	....	....
			114	229	26,126	....	....	....	....	....	....	....	....	....
	All other power:	1-200	121	104	12,657	8,804	51	4,492	1	15	9	278	77	4,019
		201-500	126	383	41,945	31,975	135	19,116	2	480	3	130	157	12,255
		501 and above	108	1,770	191,194	168,151	276	72,881	42	66,270	3	554	193	28,446
			355	692	245,796	208,930	467	96,483	45	66,765	15	962	427	44,720
	Total power		623	610	380,229	317,237	694	170,621	79	100,934	15	962	427	44,720
	Grand total		636	....	390,229	317,237	694	170,621	79	100,934	15	962	427	44,720
2e. Carpets and rugs.	No power		5	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	13	134	1,748	1,748	15	1,748	0	0	....	....	....	....
		201-500	7	334	2,335	2,335	9	2,260	1	75	....	....	....	....
		501 and above	4	1,770	7,080	7,080	20	6,380	1	700	....	....	....	....
			24	465	11,163	11,163	44	10,388	2	775	....	....	....	....
	Purchased electric power only:	1-200	9	59	533	....	....	....	....	....	....	....	....	....
		201-500	1	260	260	....	....	....	....	....	....	....	....	....
		501 and above	2	1,711	3,422	....	....	....	....	....	....	....	....	....
			12	351	4,215	....	....	....	....	....	....	....	....	....
	All other power:	1-200	15	32	476	255	3	170	0	0	2	85	0	0
		201-500	7	296	2,075	1,157	7	857	0	0	0	0	1	300
		501 and above	7	2,010	14,070	13,129	18	9,167	4	2,975	0	0	6	987
			29	570	16,621	14,541	28	10,194	4	2,975	2	85	7	1,287
	Total power		65	490	31,999	25,704	72	20,582	6	3,750	2	85	7	1,287
	Grand total		70	....	31,999	25,704	72	40,582	6	3,750	2	85	7	1,287

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	473	1,803	473	1,803	32,182	21,020	49,820	260
....	....	....	....	1,741	3,199	1,741	3,199	46,048	13,799	55,099	0
....	....	....	....	4,880	10,263	4,880	10,263	27,226	17,244	41.644	0
....	....	....	....	7,094	15,265	7,094	15,265	105,456	52,063	146,563	260
20,908	7,348	20,908	....	7,348	20,909	....	....	23,446	7,672	28,672	27
6,749	2,169	6,749	....	2,169	6,749	....	....	7,212	2,434	8,934	0
5,243	1,214	5,243	....	1,214	5,243	....	....	2,708	5,584	8,014	0
32,900	10,731	32,900	....	10,731	32,900	....	....	33,366	15,690	45,620	27
4,600	383	1,615	2,985	557	2,130	174	515	15,008	8,847	22,347	96
2,479	569	2,479	0	812	3,008	243	529	22,074	12,570	32,370	0
19,030	5,311	19,030	0	6,437	28,912	1,126	9,882	82,636	99,148	173,648	0
26,109	6,263	23,124	2,985	7,806	34,050	1,543	10,926	119,718	120,565	120,565	228.365
59,009	16,994	56,024	2,985	25,631	82,215	8,637	26,191	258,540	188,318	420,548	383
59,009	16,994	56.024	2,985	25,631	82,215	8,637	26,191	258,569	188,958	421,214	383
....	....	....	....	....	....	....	....	10	1,060	1,069	0
....	....	....	....	94	521	94	521	7,930	60,097	67,247	45
....	....	....	....	439	2,435	439	2,435	21,367	69,234	88,434	0
....	....	....	....	2,589	51,771	2,589	51,771	64,154	268,567	326,267	0
....	....	....	....	3,122	54,727	3,122	54,727	93,154	397,898	481,948	45
6,989	912	6,989	....	912	6,989	....	....	1,689	14,250	15,770	2
7,663	588	7,663	....	588	7,663	....	....	1,768	14,171	15,761	877
11,474	899	11,474	....	899	11,474	....	....	550	23,851	24,301	0
26,126	2,399	26,126	....	2,399	26,126	....	....	4,007	52,272	55,832	879
3,853	219	2,290	1,563	382	2,834	163	544	2,054	37,083	38,933	550
9,970	968	9,420	550	1,433	14,212	465	4,792	12,327	168,116	179,216	434
23,043	2,150	23,043	0	8,140	93,264	5,990	70,221	69,663	553,688	616,488	86
36,866	3,337	34,753	2,113	9,955	110,310	6,618	75,557	84,044	758,887	834,637	1,070
62,992	5,736	60,879	2,113	15,476	191,163	9,740	130,284	181,502	1,209,057	1,372,417	1,994
62,992	5,736	60,879	2,113	15,476	191,163	9,740	130,284	181,512	1,210,117	1,373,486	1,994
....	....	....	....	....	....	....	....	178	7,054	7,212	0
....	....	....	....	37	426	37	426	1,759	11,312	12,892	0
....	....	....	....	103	524	103	524	5,712	7,096	12,246	0
....	....	....	....	388	3,494	388	3,494	19,610	23,841	41,441	0
....	....	....	....	528	4,444	528	4,444	27,081	42,249	66,579	0
533	68	533	....	68	533	....	....	119	5,424	5,531	0
260	97	260	....	97	260	....	....	0	497	497	0
3,422	212	3,422	....	212	3,422	....	....	0	35,804	35,804	0
4,215	377	4,215	....	377	4,215	....	....	119	41,725	41,832	0
221	22	221	0	22	221	0	0	1,343	1,364	2,574	0
918	218	918	0	223	993	5	75	1,140	9,828	10,858	300
941	30	941	0	1,266	8,958	1,236	8,017	6,462	123,232	129,032	0
2,080	270	2,080	0	1,511	10,172	1,241	8,092	8,945	134,424	142,464	300
6,295	647	6,295	0	2,416	18,831	1,769	12,536	36,145	218,398	250,875	300
6,295	647	6,295	0	2,416	18,831	1,769	12,536	36,323	225,452	258,087	300

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
			Number.	Average size (horsepower).	Aggregate horsepower.	Prime movers.								
						Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2f. Dyeing and finishing.	No power		50											
	Steam power only:	1-200	114	77	8,803	8,803	206	8,668	8	135				
		201-500	18	345	6,237	6,237	103	5,537	3	700				
		501 and above	33	1,415	46,847	46,847	722	31,145	25	15,702				
			165	374	61,887	61,887	1,031	45,350	36	16,537				
	Purchased electric power only:	1-200	226	28	6,344									
		201-500	10	278	2,784									
		501 and above	1	1,131	1,131									
			237	45	10,259									
	All other power:	1-200	101	80	8,141	6,088	139	4,006	8	126	16	311	10	1,645
		201-500	33	318	10,560	7,501	142	6,441	0	0	2	35	12	1,025
		501 and above	29	1,780	51,673	43,441	443	18,701	31	14,425	10	1,788	49	8,527
			163	431	70,374	57,030	724	29,148	39	14,551	28	2,134	71	11,197
	Total power		565	252	142,520	118,917	1,755	74,498	75	31,088	28	2,134	71	11,197
	Grand total		615		142,520	118,917	1,755	74,498	75	31,088	28	2,134	71	11,197
2g. All other fabrics and materials.	No power		21											
	Steam power only:	1-200	31	98	3,054	3,054	36	3,054	0	0				
		201-500	24	314	7,503	7,503	41	7,003	1	500				
		501 and above	14	1,925	26,988	26,988	58	21,696	13	5,292				
			69	545	37,545	37,545	135	31,753	14	5,792				
	Purchased electric power only:	1-200	113	23	2,625									
		201-500	5	194	971									
		501 and above	3	768	2,304									
			121	49	5,900									
	All other power:	1-200	53	102	5,422	3,844	33	2,895	0	0	7	69	13	880
		201-500	28	297	8,333	7,082	25	3,710	0	0	2	170	30	3,202
		501 and above	21	2,230	46,878	32,698	40	9,386	5	7,875	2	227	33	15,210
			102	595	60,633	43,624	98	15,991	5	7,875	11	466	76	19,292
	Total power		292	356	104,078	81,169	233	47,744	19	13,667	11	466	76	19,292
	Grand total		313		104,078	81,169	233	47,744	19	13,667	11	466	76	19,292
2h. Clothing.	No power		1,614											
	Steam power only:	1-200	80	72	5,783	5,783	91	5,688	2	95				
		201-500	22	307	6,769	6,769	50	6,769	0	0				
		501 and above	3	515	1,545	1,545	11	1,535	1	10				
			105	134	14,097	14,097	152	13,992	3	105				
	Purchased electric power only:	1-200	12,605	4	49,332									
		201-500	4	265	1,060									
		501 and above	1	678	678									
			12,610	4	51,070									
	All other power:	1-200	291	23	6,632	4,269	53	2,071	1	10	179	1,608	14	580
		201-500	11	321	3,537	2,856	25	2,781	0	0	0	0	2	75
		501 and above	7	1,225	8,578	5,375	13	2,665	4	2,150	0	0	7	560
			309	61	18,747	12,500	91	7,517	5	2,160	179	1,608	23	1,215
	Total power		13,024	6	83,914	26,597	243	21,509	8	2,265	179	1,608	23	1,215
	Grand total		14,638		83,914	26,597	243	21,509	8	2,265	179	1,608	23	1,215

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
....	....	....	....	....	....	....	....	653	6,546	7,088	0
....	....	....	....	233	1,541	233	1,541	37,950	83,395	117,395	0
....	....	....	....	480	2,596	480	2,596	16,035	53,452	67,852	0
....	....	....	....	2,931	29,107	2,931	29,107	218,474	344,156	540,156	703
....	....	....	....	3,644	33,244	3,644	33,244	272,459	481,003	725,403	703
6,344	1,524	6,344	....	1,524	6,344	....	....	21,165	41,451	60,351	226
2,784	355	2,784	....	355	2,784	....	....	3,188	21,546	24,406	0
1,131	62	1,131	....	62	1,131	....	....	30	8,980	9,007	0
10,259	1,941	10,259	....	1,941	10,259	....	....	24,383	71,977	93,764	226
2,053	298	1,695	358	351	2,515	53	820	21,300	56,367	75,467	0
3,059	338	2,839	220	451	3,817	113	978	43,171	58,249	97,049	91
8,232	792	8,232	....	2,297	29,819	1,505	21,587	67,535	276,931	337,531	195
13,344	1,428	12,766	578	3,099	36,151	1,671	23,385	132,006	391,547	510,047	286
23,603	3,369	23,025	578	8,684	79,654	5,315	56,629	428,818	944,527	1,329,214	1,215
23,603	3,369	23,025	578	8,684	79,654	5,315	56,629	429,501	951,073	1,336,302	1,215
....	....	....	....	....	....	....	....	1,078	0	970	6
....	....	....	....	8	216	8	216	6,003	15,133	20,535	7
....	....	....	....	317	1,957	317	1,957	18,747	29,347	46,219	0
....	....	....	....	1,100	9,398	1,100	9,398	58,195	19,538	71,918	17,408
....	....	....	....	1,425	11,571	1,425	11,571	82,945	64,018	138,672	17,415
2,625	410	2,625	....	410	2,625	....	....	1,613	8,958	10,409	844
971	116	971	....	116	971	....	....	0	2,487	2,487	0
2,304	104	2,304	....	104	2,304	....	....	0	6,224	6,224	0
5,900	630	5,900	....	630	5,900	....	....	1,613	17,669	19,120	844
1,578	181	1,315	263	234	1,463	53	148	9,084	21,795	29,967	237
1,251	99	1,251	0	136	1,704	37	453	2,695	20,950	23,330	0
14,180	559	14,180	0	1,028	29,045	469	14,865	31,761	48,918	77,484	0
17,009	839	16,746	263	1,398	32,212	559	15,466	43,540	91,663	130,781	237
22,909	1,469	22,646	263	3,453	49,683	1,984	27,037	128,098	173,350	288,573	18,496
22,909	1,469	22,646	263	3,453	49,683	1,984	27,037	129,176	173,350	289,543	18,502
....	....	....	....	....	....	....	....	2,282	415	2,465	15
....	....	....	....	482	2,023	482	2,023	17,978	21,368	37,568	0
....	....	....	....	1,534	2,662	1,534	2,662	12,463	20,437	31,537	0
....	....	....	....	294	868	294	868	572	4,670	5,165	0
....	....	....	....	2,310	5,553	2,310	5,553	31,013	46,475	74,290	0
49,332	39,645	49,332	....	39,645	49,332	....	....	232,269	20,474	228,474	8,964
1,060	60	1,060	....	60	1,060	....	....	511	592	1,052	0
678	49	678	....	49	678	....	....	0	0	0	0
51,070	39,754	51,070	....	39,754	51,070	....	....	232,780	21,066	229,526	8,964
2,363	506	1,602	761	668	2,133	162	531	6,559	11,449	17,349	369
681	189	681	0	426	1,620	237	939	3,505	15,858	19,008	0
3,203	655	3,203	0	1,231	6,328	576	3,125	3,080	34,883	37,663	0
6,247	1,350	5,486	761	2,325	10,081	975	4,595	13,144	62,190	74,020	369
57,317	41,104	56,556	761	44,389	66,704	3,285	10,148	276,937	129,731	377,836	9,333
57,317	41,104	56,556	761	44,389	66,704	3,285	10,148	279,219	130,146	380,301	9,348

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
						Prime movers.								
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
21. All other textiles.	No power		151	......	......	......	......	......	......	......	......	......	......	......
	Steam power only:													
		1-200	37	103	3,797	3,797	42	3,722	1	75	......	......	......	......
		201-500	3	329	986	986	6	720	2	266	......	......	......	......
		501 and above	5	1,953	9,765	9,765	38	8,365	2	1,400	......	......	......	......
			45	323	14,548	14,548	86	12,807	5	1,741	......	......	......	......
	Purchased electric power only:													
		1-200	582	9	5,436	......	......	......	......	......	......	......	......	......
		201-500	6	314	1,883	......	......	......	......	......	......	......	......	......
		501 and above	5	1,013	5,064	......	......	......	......	......	......	......	......	......
			593	21	12,383	......	......	......	......	......	......	......	......	......
	All other power:													
		1-200	60	44	2,612	2,046	12	745	0	0	32	636	16	665
		201-500	13	385	5,000	2,992	13	2,225	2	300	0	0	4	467
		501 and above	6	2,238	13,426	3,952	71	3,950	0	0	1	2	0	0
			79	266	21,038	8,990	96	6,920	2	300	33	638	20	1,132
		Total power	717	67	47,969	23,538	182	19,727	7	2,041	33	638	20	1,132
		Grand total	868	......	47,969	23,538	182	19,727	7	2,041	33	638	20	1,132
3a. Blast furnaces.	Steam power only:													
		1-200	3	90	275	275	7	275	0	0	......	......	......	......
		201-500	1	450	450	450	1	450	0	0	......	......	......	......
		501 and above	14	5,340	74,814	74,814	189	54,694	7	20,120	......	......	......	......
			18	4,200	75,539	75,539	197	55,419	7	20,120	......	......	......	......
	All other power:													
		201-500	1	460	460	410	3	410	0	0	0	0	0	0
		501 and above	8	13,480	107,834	107,446	55	30,015	3	2,900	39	74,405	4	126
			9	12,030	108,294	107,856	58	30,425	3	2,900	39	74,405	4	126
		Total (power)	27	6,800	183,833	183,395	255	85,844	10	23,020	39	74,405	4	126
3b. Steel works and rolling mills.	Steam power only:													
		1-200	1	1	110	110	2	110	0	0	......	......	......	......
		201-500	3	290	870	870	15	870	0	0	......	......	......	......
		501 and above	40	4,630	185,261	185,261	513	151,013	44	34,248	......	......	......	......
			44	4,240	186,241	186,241	530	151,993	44	34,248	......	......	......	......
	Purchased electric power only:													
		1-200	10	152	1,524	......	......	......	......	......	......	......	......	......
		201-500	2	356	712	......	......	......	......	......	......	......	......	......
		501 and above	6	2,040	12,245	......	......	......	......	......	......	......	......	......
			18	804	14,481	......	......	......	......	......	......	......	......	......
	All other power:													
		1-200	3	110	331	235	4	235	0	0	0	0	0	0
		201-500	5	370	1,841	1,728	16	1,728	16	1,728	0	0	0	0
		501 and above	42	8,780	368,772	301,739	597	199,964	94	41,093	25	59,747	8	935
			50	7,418	370,944	303,703	617	201,927	94	41,093	25	59,747	8	935
		Total (power)	112	5,100	571,666	489,943	1,147	353,920	138	75,341	25	59,747	8	935
3c. Locomotives, not by railroads.	Steam power only:													
		501 and above	2	1,343	2,685	2,685	12	2,685	0	0	......	......	......	......
	All other power:													
		501 and above	3	22,807	68,421	19,900	40	14,400	6	5,000	2	500	0	0
		Total (power)	5	14,221	71,106	22,585	52	17,085	6	5,000	2	500	0	0

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
....	....	....	....	....	....	....	....	309	60	338	4
....	....	....	....	96	725	96	725	6,511	16,236	22,096	1,148
....	....	....	....	205	1,145	205	1,145	1,522	23,770	25,140	1,458
....	....	....	....	776	7,102	776	7,102	14,919	79,822	93,222	1,072
....	....	....	....	1,077	8,972	1,077	8,972	22,952	119,828	140,458	3,678
5,436	2,064	5,436	....	2,064	5,436	....	....	3,395	11,702	14,762	165
1,883	154	1,883	....	154	1,883	....	....	344	8,495	8,805	50
5,064	396	5,064	....	396	5,064	....	....	579	17,991	18,521	52
12,383	2,614	12,383	....	2,614	12,383	....	....	4,318	38,188	42,088	267
566	186	399	167	186	399	0	0	1,175	2,309	3,369	0
2,008	170	2,008	0	195	2,167	25	159	8	27,838	27,845	53
9,474	594	9,474	0	597	9,481	3	7	23,582	45,505	66,705	0
12,048	950	11,881	167	978	12,047	28	166	24,765	75,652	97,919	53
24,431	3,564	24,264	167	4,669	33,402	1,105	9,138	52,035	233,668	280,465	3,998
24,431	3,564	24,264	167	4,669	33,402	1,105	9,138	52,344	233,728	280,803	4,002
....	....	....	....	2	100	2	100	0	744	744	54,977
....	....	....	....	0	0	0	0	0	1,500	1,500	75,000
....	....	....	....	407	16,513	407	16,513	27,330	209,196	233,696	1,366,358
....	....	....	....	409	16,613	409	16,613	27,330	211,440	235,940	1,496,335
50	1	50	0	1	50	0	0	0	1,400	1,400	70,000
388	8	388	0	306	65,055	298	64,667	13,186	60,614	72,414	1,604,486
438	9	438	0	307	65,105	298	64,667	13,186	62,014	73,814	1,674,486
438	9	438	0	716	81,718	707	81,280	40,516	273,454	309,754	3,170,821
....	....	....	....	1	15	1	15	0	556	556	0
....	....	....	....	101	1,480	101	1,480	148	23,540	23,674	8,497
....	....	....	....	4,203	83,349	4,203	83,349	101,584	1,434,581	1,526,007	19,507
....	....	....	....	4,305	84,844	4,305	84,844	101,732	1,458,677	1,550,237	23,004
1,524	79	1,524	....	79	1,524	....	....	141	1,417	1,543	276
712	62	712	....	62	712	....	....	81	73	146	0
12,245	327	12,245	....	327	12,245	....	....	952	19,302	20,157	2,174
14,481	468	14,481	....	468	14,481	....	....	1,174	20,792	21,846	2,450
96	13	96	0	13	96	0	0	0	2,400	2,400	2,000
113	11	113	0	55	357	44	244	150	19,920	20,065	926
67,033	5,583	66,783	250	18,236	412,418	12,853	345,635	418,215	2,047,270	2,423,668	60,313
67,242	5,607	66,992	250	18,304	412,871	12,697	345,635	418,365	2,069,590	2,446,123	63,244
81,723	6,075	81,473	250	23,077	512,196	17,002	430,723	521,271	3,549,059	4,018,206	88,698
....	....	....	....	264	11,531	264	11,531	23,178	6,994	27,794	1,602
48,521	2,396	48,521	0	3,660	73,835	1,264	25,314	9,620	209,735	218,385	18,778
48,521	2,396	48,521	0	3,924	85,366	1,528	36,845	32,798	216,628	246,179	20,380

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
						Prime movers.								
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
3d. All other iron and steel products.	No power		407	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	452	71	32,166	32,166	535	31,713	9	453	....	....	....	....
		201-500	87	333	29,030	29,030	174	27,045	16	1,965	....	....	....	....
		501 and above	72	1,920	138,052	138,052	337	70,878	79	67,174	....	....	....	....
			611	326	199,248	199,248	1,046	129,636	104	69,612	....	....	....	....
	Purchased electric power only:	1-200	3,701	26	95,580	....	....	....	....	....	....	....	....	....
		201-500	142	312	44,489	....	....	....	....	....	....	....	....	....
		501 and above	103	1,050	118,676	....	....	....	....	....	....	....	....	....
			3,946	655	258,745	....	....	....	....	....	....	....	....	....
	All other power:	1-200	1,341	40	54,293	38,753	319	16,741	7	286	960	15,827	167	5,899
		201-500	165	320	52,501	32,872	215	24,069	12	785	56	2,978	75	5,040
		501 and above	155	2,290	354,363	208,708	465	111,465	54	77,578	63	10,622	71	9,043
			1,661	278	461,157	280,333	999	152,275	73	78,649	1,079	29,427	313	19,982
	Total power		6,218	148	919,150	479,581	2,045	281,911	177	148,261	1,079	29,427	313	19,982
	Grand total		6,625	....	919,150	479,581	2,045	281,911	177	148,261	1,079	29,427	313	19,982
4a. Lumber.	No power		107	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	1,090	38	41,477	41,477	1,189	41,117	8	360	....	....	....	....
		201-500	9	314	2,827	2,827	18	2,827	0	0	....	....	....	....
			1,099	40	44,304	44,304	1,207	43,944	8	360	....	....	....	....
	Purchased electric power only:	1-200	54	46	2,475	....	....	....	....	....	....	....	....	....
		201-500	2	378	757	....	....	....	....	....	....	....	....	....
			56	58	3,232	....	....	....	....	....	....	....	....	....
	All other power:	1-200	466	44	20,476	19,681	103	4,032	1	25	211	4,557	364	11,067
		201-500	15	278	4,179	3,407	16	2,260	0	0	9	423	14	724
		501 and above	5	806	4,031	3,896	54	2,786	2	700	3	10	2	400
			486	59	28,686	26,984	173	9,078	3	725	223	4,990	380	12,191
	Total power		1,641	46	76,222	71,288	1,380	53,022	11	1,085	223	4,990	380	12,191
	Grand total		1,748	....	76,222	71,288	1,380	53,022	11	1,085	223	4,990	380	12,191
1b. Furniture and all other lumber products.	No power		803	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	509	84	42,695	42,695	549	42,255	5	440	....	....	....	....
		201-500	81	303	24,502	24,502	121	24,242	2	260	....	....	....	....
		501 and above	24	890	21,340	21,340	77	17,835	8	3,505	....	....	....	....
			614	144	88,537	88,537	747	84,332	15	4,205	....	....	....	....
	Purchased electric power only:	1-200	1,621	24	39,653	....	....	....	....	....	....	....	....	....
		201-500	30	196	8,867	....	....	....	....	....	....	....	....	....
		501 and above	4	743	2,973	....	....	....	....	....	....	....	....	....
			1,655	31	51,493	....	....	....	....	....	....	....	....	....
	All other power:	1-200	723	44	32,072	23,888	225	13,524	2	30	327	4,834	178	5,500
		201-500	60	296	17,764	12,372	84	10,859	0	0	5	114	27	1,399
		501 and above	17	845	14,445	10,320	57	9,548	1	150	2	9	6	613
			800	80	64,281	46,580	366	33,931	3	180	334	4,957	211	7,512
	Total power		3,069	66	204,311	135,117	1,113	118,263	18	4,385	334	4,957	211	7,512
	Grand total		3,872	....	204,311	135,117	1,113	118,263	18	4,385	334	4,957	211	7,512

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horse-power).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horse-power.		Number.	Horse-power.	Number.	Horse-power.				
16	17	18	19	20	21	22	23	24	25	26	27
....	....	....	....	....	....	....	....	4,230	3,304	7,114	1,077
....	....	....	....	1,213	8,713	1,213	8,713	69,628	153,924	216,564	48,561
....	....	....	....	1,900	19,738	1,900	19,738	40,664	105,987	141,987	24,465
....	....	....	....	9,491	133,800	9,491	133,800	243,808	598,265	817,865	113,638
....	....	....	....	12,604	162,251	12,604	162,251	354,100	858,176	1,176,416	186,664
95,580	13,971	95,580	....	13,971	95,580	....	....	66,177	102,742	162,242	109,625
44,489	4,158	44,489	....	4,158	44,489	....	....	24,835	58,478	80,778	31,114
118,676	10,144	118,676	....	10,144	118,676	....	....	32,453	147,478	176,578	63,708
258,745	28,273	258,745	....	28,273	258,745	....	....	123,465	308,698	419,598	204,447
15,540	1,654	13,033	2,507	2,331	17,617	677	4,584	43,195	101,056	140,056	38,735
19,629	1,726	19,454	175	2,686	30,564	960	11,110	40,088	137,558	173,558	39,182
145,655	9,093	145,455	200	14,068	206,497	4,975	61,042	152,280	931,306	1,068,000	95,199
180,824	12,473	177,942	2,882	19,085	254,678	6,612	76,736	235,563	1,169,920	1,381,614	173,116
439,569	40,746	436,687	2,882	59,962	675,674	19,216	238,987	713,128	2,336,794	2,977,628	564,227
439,569	40,746	436,687	2,882	59,962	675,674	19,216	238,987	717,358	2,340,098	2,984,744	565,304
....	....	....	....	....	....	....	....	0	1,105	1,105	0
....	....	....	....	10	65	10	65	1,012	2,183	3,090	20
....	....	....	....	20	415	20	415	0	1,897	1,897	89
....	....	....	....	30	480	30	480	1,012	4,080	4,987	109
2,475	116	2,475	....	116	2,475	....	....	11	100	110	0
757	64	757	....	64	757	....	....	0	0	0	0
3,232	180	3,232	....	180	3,232	....	....	11	100	110	0
795	39	730	65	45	750	6	20	109	184	292	0
772	99	772	0	135	1,052	36	280	0	1,705	1,705	0
135	13	135	0	146	2,341	133	2,206	25	12,054	12,076	166
1,702	151	1,637	65	326	4,143	175	2,506	134	13,943	14,073	166
4,934	331	4,869	65	536	7,855	205	2,986	1,157	18,123	19,170	275
4,934	331	4,869	65	536	7,855	205	2,986	1,157	19,228	20,275	275
....	....	....	....	....	....	....	....	3,096	1,405	4,195	1
....	....	....	....	409	3,186	409	3,186	35,521	75,896	107,864	864
....	....	....	....	1,100	9,068	1,100	9,068	6,057	87,439	92,894	1,220
....	....	....	....	888	9,661	888	9,661	4,665	44,477	48,675	1,242
....	....	....	....	2,397	21,915	2,397	21,915	46,243	207,812	249,433	3,326
39,653	6,406	39,653	....	6,406	39,653	....	....	13,779	13,524	25,926	1,636
8,867	961	8,867	....	961	8,867	....	....	897	1,629	2,437	3,099
2,973	320	2,973	....	320	2,973	....	....	870	2,294	3,077	0
51,493	7,687	51,493	....	7,687	51,493	....	....	15,546	17,447	31,440	4,735
8,184	864	5,114	3,070	1,098	6,608	234	1,494	9,962	31,947	40,947	1,141
5,392	504	5,142	250	823	7,910	319	2,768	3,262	25,239	28,174	1,678
4,125	318	4,125	0	722	7,937	404	3,812	7,215	41,888	48,379	0
17,701	1,686	14,381	3,320	2,643	22,455	957	8,074	20,439	99,074	117,500	2,819
69,194	9,373	65,874	3,320	12,727	95,863	3,354	29,989	82,228	324,333	398,373	10,880
69,194	9,373	65,874	3,320	17,727	95,863	3,354	29,989	85,324	325,738	402,568	10,881

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
			Number.	Average size (horsepower).	Aggregate horsepower.	Prime movers.								
						Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
5a. Leather, tanned, curried, and finished.	No power		14	......	......	......	......	......	......	......	......	......	......	......
		1-200	69	98	6,710	6,710	82	6,510	4	200	......	......	......	......
		201-500	27	291	7,895	7,895	56	7,595	3	300	......	......	......	......
		501 and above	17	1,280	21,784	21,784	49	13,147	15	8,637	......	......	......	......
			113	322	36,389	36,389	187	27,252	22	9,137	......	......	......	......
	Purchased electric power only:	1-200	94	55	5,123	......	......	......	......	......	......	......	......	......
		201-500	12	383	4,603	......	......	......	......	......	......	......	......	......
		501 and above	2	586	1,173	......	......	......	......	......	......	......	......	......
			108	101	10,899	......	......	......	......	......	......	......	......	......
	All other power:	1-200	63	96	6,061	4,230	55	4,017	0	0	5	73	3	140
		201-500	50	295	14,772	9,819	82	9,155	0	0	3	335	4	329
		501 and above	18	1;100	19,808	8,047	32	7,500	0	0	1	20	5	527
			131	310	40,641	22,096	169	20,672	0	0	9	428	12	996
		Total power	352	250	87,929	58,485	356	47,924	22	9,137	9	428	12	996
		Grand total	366	......	87,929	58,485	356	47,924	22	9,137	9	428	12	996
5b. Leather finished products.	No power		521	......	......	......	......	......	......	......	......	......	......	......
	Steam power only:	1-200	151	84	12,629	12,629	163	12,629	0	0	......	......	......	......
		201-500	19	320	6,095	6,095	32	6,055	1	40	......	......	......	......
		501 and above	8	1,827	14,620	14,620	19	5,025	10	9,595	......	......	......	......
			178	187	33,344	33,344	214	23,709	11	9,635	......	......	......	......
	Purchased electric power only:	1-200	1,750	11	18,799	......	......	......	......	......	......	......	......	......
		201-500	20	293	5,863	......	......	......	......	......	......	......	......	......
		501 and above	5	1,058	5,289	......	......	......	......	......	......	......	......	......
			1,775	17	29,951	......	......	......	......	......	......	......	......	......
	All other power:	1-200	367	33	12,174	3,522	44	2,488	0	0	75	871	9	163
		201-500	30	312	9,352	6,605	38	4,670	7	1,355	0	0	6	580
		501 and above	5	1,066	5,331	2,505	11	2,505	0	0	0	0	0	0
			402	67	26,857	12,632	93	9,663	7	1,355	75	871	15	743
		Total power	2,355	38	90,152	45,976	307	33,372	18	10,990	75	871	15	743
		Grand total	2,876	......	90,152	45,976	307	33,372	18	10,990	75	871	15	743
6a. Paper and wood pulp.	Steam power only:	1-200	10	172	1,720	1,720	18	1,720	0	0	......	......	......	......
		201-500	17	345	5,876	5,876	46	5,376	2	500	......	......	......	......
		501 and above	33	2,050	67,879	67,879	251	52,461	20	15,418	......	......	......	......
			60	1,258	75,475	75,475	315	59,557	22	15,918	......	......	......	......
	Purchased electric power only:	1-200	3	136	409	......	......	......	......	......	......	......	......	......
		201-500	3	347	1,040	......	......	......	......	......	......	......	......	......
		501 and above	5	1,009	5,047	......	......	......	......	......	......	......	......	......
			11	590	6,496	......	......	......	......	......	......	......	......	......
	All other power:	1-200	33	204	6,737	6,624	55	4,204	0	0	0	0	50	2,420
		201-500	55	338	18,596	16,023	82	9,208	1	150	4	50	89	6,615
		501 and above	138	2,700	374,782	327,901	633	111,858	38	21,988	11	1,746	543	192,309
			226	1,770	400,115	350,548	770	125,270	39	22,138	15	1,796	682	201,344
		Total power	297	1,620	482,086	426,023	1,085	184,827	61	38,056	15	1,796	682	201,344

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).	Number.	Horsepower.	Number.	Horsepower.	Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.									
16	17	18	19	20	21	22	23	24	25	26	27
....	....	....	....	....	....	....	....	925	762	1,594	94
....	....	....	....	60	713	60	713	3,916	30,564	34,092	0
....	....	....	....	96	937	96	937	9,871	62,323	71,323	0
....	....	....	....	1,698	23,541	1,698	23,541	26,609	170,468	194,417	58
....	....	....	....	1,854	25,191	1,854	25,191	40,396	263,355	299,832	58
5,123	603	5,123	....	603	5,123	....	....	2,586	20,505	22,835	2,000
4,603	337	4,603	....	337	4,603	....	....	497	21,270	21,720	200
1,173	32	1,173	....	32	1,173	....	....	0	1,802	1,802	0
10,899	972	10,899	....	972	10,899	....	....	3,083	43,577	46,357	2,200
1,831	130	1,468	363	175	2,006	45	538	4,243	22,795	26,611	
4,953	354	4,953	0	483	6,656	129	1,703	14,558	53,215	66,319	60
11,761	545	11,761	0	810	14,344	265	2,583	14,943	47,673	61,119	8
18,545	1,029	18,182	363	1,468	23,006	439	4,824	33,744	123,683	154,049	68
29,444	2,001	29,081	363	4,294	59,096	2,293	30,015	77,223	430,615	500,238	2,326
29,444	2,001	29,081	363	4,294	59,096	2,293	30,015	78,148	431,377	501,832	2,420
....	....	....	....	....	....	....	....	1,153	470	1,505	1
....	....	....	....	456	2,409	456	2,409	17,223	44,372	59,872	443
....	....	....	....	403	2,701	403	2,701	8,422	13,427	20,987	0
....	....	....	....	1,838	9,948	1,838	9,948	12,029	62,528	73,328	0
....	....	....	....	2,697	15,058	2,697	15,058	37,674	120,327	154,187	443
18,799	5,007	18,799	....	5,007	18,799	....	....	15,352	26,721	40,621	207
5,863	1,215	5,863	....	1,215	5,863	....	....	3,852	11,317	14,777	0
5,289	607	5,289	....	607	5,289	....	....	1,885	7,340	9,030	0
29,951	6,829	29,951	....	6,829	29,951	....	....	21,089	45,378	64,428	207
8,652	605	2,650	6,002	675	2,946	70	296	2,715	13,143	15,403	195
2,747	533	2,747	0	649	3,612	116	865	3,680	27,798	31,103	0
2,826	308	2,826	0	333	3,283	25	457	2,896	8,642	11,242	0
14,225	1,446	8,223	6,002	1,657	9,841	211	1,618	9,291	49,578	57,748	195
44,176	8,275	38,174	6,002	11,183	54,850	2,908	16,676	68,054	215,283	276,363	845
44,176	8,275	38,174	6,002	11,183	54,850	2,908	16,676	69,207	215,753	277,868	846
....	....	....	....	2	159	2	159	5,175	4,968	9,618	0
....	....	....	....	34	1,013	34	1,013	8,871	73,891	81,851	0
....	....	....	....	757	11,392	757	11,392	36,313	677,183	709,783	1,318
....	....	....	....	793	12,564	793	12,564	50,359	756,042	801,252	1,318
409	39	409	....	39	409	....	....	4,264	2,000	5,840	0
1,040	26	1,040	....	26	1,040	....	....	652	2,555	3,140	0
5,047	102	5,047	....	102	5,047	....	....	0	31,788	31,788	0
6,496	167	6,496	....	167	6,496	....	....	4,916	36,343	40,768	0
113	6	113	0	19	255	13	142	11,613	35,348	45,848	0
2,573	124	2,573	0	174	3,366	50	793	15,851	78,855	93,055	522
46,881	1,542	45,371	1,510	3,202	89,697	1,660	44,326	463,652	849,164	1,266,164	8,173
49,567	1,672	48,057	1,510	3,395	93,318	1,723	45,261	491,116	963,367	1,405,067	8,695
56,063	1,839	54,553	1,510	4,355	112,378	2,516	57,825	546,391	1,755,752	2,247,087	10,013

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments. Number.	Establishments. Average size (horsepower).	Power-supply equipment. Aggregate horsepower.	Prime movers. Total horsepower.	Steam engines. Number.	Steam engines. Horsepower.	Steam turbines. Number.	Steam turbines. Horsepower.	Internal-combustion engines. Number.	Internal-combustion engines. Horsepower.	Water wheels. Number.	Water wheels. Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
6b. Manufactures of paper.	No power		95	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	50	63	3,164	3,164	52	3,024	2	140	....	....	....	....
		201-500	13	312	4,055	4,055	25	4,055	0	0	....	....	....	....
		501 and above	11	1,303	14,329	14,329	32	7,557	16	6,772	....	....	....	....
			74	290	21,548	21,548	109	14,636	18	6,912	....	....	....	....
	Purchased electric power only:	1-200	807	18	14,195	....	....	....	....	....	....	....	....	....
		201-500	10	303	3,028	....	....	....	....	....	....	....	....	....
		501 and above	1	846	846	....	....	....	....	....	....	....	....	....
			818	22	18,069	....	....	....	....	....	....	....	....	....
	All other power:	1-200	129	37	4,758	3,364	34	1,981	0	0	64	919	12	514
		201-500	12	337	4,048	2,630	15	1,956	1	35	1	4	7	635
		501 and above	5	1,493	7,464	4,501	11	2,651	1	1,500	0	0	3	350
			146	112	16,270	10,495	60	6,538	2	1,535	65	923	22	1,499
	Total power		1,038	54	55,887	32,043	169	21,174	20	8,447	65	923	22	1,499
	Grand total		1,133	....	55,887	32,043	169	21,174	20	8,447	65	923	22	1,499
6c. Printing and publishing.	No power		2,504	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	55	53	2,927	2,927	60	2,917	1	10	....	....	....	....
		201-500	14	312	4,371	4,371	30	4,146	1	225	....	....	....	....
		501 and above	12	1,150	13,794	13,794	47	13,574	2	220	....	....	....	....
			81	261	21,092	21,092	137	20,637	4	455	....	....	....	....
	Purchased electric power only:	1-200	6,333	15	97,799	....	....	....	....	....	....	....	....	....
		201-500	42	297	12,531	....	....	....	....	....	....	....	....	....
		501 and above	17	1,040	17,781	....	....	....	....	....	....	....	....	....
			6,392	20	128,111	....	....	....	....	....	....	....	....	....
	All other power:	1-200	462	17	7,980	4,953	46	2,453	2	42	333	2,171	16	287
		201-500	12	273	3,284	1,560	10	965	0	0	5	195	8	400
		501 and above	9	888	7,989	4,105	28	3,805	1	200	1	100	0	0
			483	40	19,253	10,618	84	7,223	3	242	339	2,466	24	687
	Total power		6,956	24	168,456	31,710	221	27,860	7	697	339	2,466	24	687
	Grand total		9,460	....	168,456	31,710	221	27,860	7	697	339	2,466	24	687
7. Liquors and beverages.	No power		121	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	77	87	6,715	6,715	150	6,570	2	145	....	....	....	....
		201-500	37	338	12,515	12,515	198	12,027	6	488	....	....	....	....
		501 and above	46	1,245	57,296	57,296	390	55,502	15	1,794	....	....	....	....
			160	480	76,526	76,526	738	74,099	23	2,427	....	....	....	....
	Purchased electric power only:	1-200	915	5	4,954	....	....	....	....	....	....	....	....	....
		501 and above	1	525	525	....	....	....	....	....	....	....	....	....
			916	6	5,479	....	....	....	....	....	....	....	....	....
	All other power:	1-200	170	34	5,826	4,544	115	3,958	1	5	96	554	20	27
		201-500	40	327	13,071	10,841	234	10,490	2	150	6	160	13	41
		501 and above	17	770	13,032	9,851	138	9,245	3	6	0	0	1	600
			227	140	31,929	25,236	487	23,693	6	161	102	714	34	668
	Total power		1,303	88	113,934	101,762	1,225	97,792	29	2,588	102	714	34	668
	Grand total		1,424	....	113,934	101,762	1,225	97,792	29	2,588	102	714	34	668

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
....	....	....	....	....	....	....	....	155	301	441	0
....	....	....	....	188	786	188	786	8,502	10,895	18,545	200
....	....	....	....	800	2,727	800	2,727	7,896	13,604	20,704	0
....	....	....	....	1,551	9,338	1,551	9,338	36,131	47,028	79,528	576
....	....	....	....	2,539	12,851	2,539	12,851	52,529	71,527	118,777	776
14,195	5,028	14,195	....	5,028	14,195	....	....	10,177	19,755	28,955	89
3,028	478	3,028	....	478	3,028	....	....	590	2,837	3,367	75
846	56	846	....	56	846	....	....	0	0	0	0
18,069	5,562	18,069	....	5,562	18,069	....	....	10,767	22,592	32,322	164
1,394	228	1,018	376	461	1,525	233	507	4,403	9,503	13,463	3
1,418	326	1,418	0	528	2,030	202	612	1,167	7,972	9,022	370
2,963	206	2,963	0	256	3,618	50	655	2,359	12,343	14,463	0
5,775	760	5,399	376	1,245	7,173	485	1,774	7,929	29,818	36,948	373
23,844	6,322	23,468	376	9,346	38,093	3,024	14,625	71,225	123,937	188,047	1,313
23,844	6,322	23,468	376	9,346	38,093	3,024	14,625	71,380	124,238	188,488	1,313
....	....	....	....	....	....	....	....	2,735	414	2,874	4
....	....	....	....	136	433	136	433	9,098	8,934	17,114	0
....	....	....	....	814	3,718	814	3,718	12,513	9,887	21,172	1,500
....	....	....	....	2,318	10,885	2,318	10,865	35,672	17,525	50,225	0
....	....	....	....	3,268	15,016	3,268	15,016	57,283	36,346	88,511	1,500
97,790	36,517	97,790	....	36,517	97,799	....	....	37,447	14,867	46,867	343
12,531	3,236	12,531	....	3,236	12,531	....	....	4,366	1,332	5,257	0
17,781	2,786	17,781	....	2,786	17,781	....	....	12,402	1,554	12,724	0
128,111	42,539	128,111	....	42,539	128,111	....	....	54,215	17,753	64,848	343
3,027	650	2,403	624	776	2,601	126	198	10,275	6,381	15,631	3
1,724	411	1,724	0	474	1,924	63	200	6,763	2,915	9,005	2
3,884	1,070	3,884	0	2,563	8,165	1,493	4,281	16,217	10,617	25,227	0
8,635	2,131	8,011	624	3,813	12,690	1,682	4,679	33,255	19,913	49,863	5
136,746	44,670	136,122	624	49,620	155,817	4,950	19,695	144,753	74,012	203,222	1,848
136,746	44,670	136,122	624	49,620	155,817	4,950	19,695	147,488	74,486	206,096	1,852
....	....	....	....	....	....	....	....	493	2,610	3,053	0
....	....	....	....	254	1,221	254	1,221	44,665	36,511	76,711	16
....	....	....	....	634	3,318	634	3,318	33,910	55,811	86,311	869
....	....	....	....	1,769	12,233	1,769	12,233	140,003	174,410	300,410	989
....	....	....	....	2,657	16,772	2,657	16,772	218,578	266,732	463,432	1,879
4,954	2,062	4,954	....	2,062	4,954	....	....	10,696	17,519	26,869	2,267
525	58	525	....	58	525	....	....	0	3,654	3,654	0
5,479	2,120	5,479	....	2,120	5,479	....	....	10,696	21,173	30,523	2,267
1,282	289	1,273	9	297	1,302	8	29	29,389	27,058	53,358	0
2,230	368	1,960	270	483	2,658	115	698	45,732	40,098	81,298	0
3,181	340	3,181	0	489	4,455	149	1,274	40,200	38,388	74,588	999
6,693	997	6,414	279	1,269	8,415	272	2,001	115,321	105,544	209,244	999
12,172	3,117	11,893	279	6,046	30,666	2,929	18,773	344,595	393,449	703,199	5,140
12,172	3,117	11,893	279	6,046	30,666	2,929	18,773	345,088	396,059	706,252	5,140

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
						Prime movers.								
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8a. Coke, not including gas-house coke.	Steam power only:	301-500	1	405	405	405	8	405	0	0	....	....	....	....
		501 and above	4	4,289	17,157	17,157	63	7,587	38	9,570	....	....	....	....
			5	3,512	17,562	17,562	71	7,992	38	9,570	....	....	....	....
	Purchased electric power only:	501 and above	3	4,255	12,765	....	....	....	....	....	....	....	....	....
	Other power:	501 and above	2	4,710	9,419	3,170	44	1,450	15	1,720	0	0	0	0
	Total power		10	3,975	39,746	20,732	115	9,442	53	11,290	0	0	0	0
8b. Explosives.	Steam power only:	1-200	2	74	148	148	3	140	1	8	....	....	....	....
		201-500	4	378	1,513	1,513	19	1,495	3	18	....	....	....	....
		501 and above	7	1,676	11,738	11,738	32	4,910	14	6,828	....	....	....	....
			13	1,033	13,399	13,399	54	6,545	18	6,854	....	....	....	....
	Purchased electric power only:	1-200	1	10	10	....	....	....	....	....	....	....	....	....
		201-500	2	310	620	....	....	....	....	....	....	....	....	....
		501 and above	1	2,142	2,142	....	....	....	....	....	....	....	....	....
			4	693	2,772	....	....	....	....	....	....	....	....	....
	All other power:	1-200	1	181	181	20	2	20	0	0	0	0	0	0
		201-500	3	267	801	480	24	395	1	30	1	14	3	41
		501 and above	2	1,185	2,369	2,150	7	1,112	1	330	0	0	22	708
			6	559	3,351	2,650	33	1,527	2	360	1	14	25	749
	Total power		23	850	19,522	16,049	87	8,072	20	7,214	1	14	25	749
8c. Gas, illuminating and heating.	No power		63	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	88	61	5,360	5,360	187	4,055	46	1,305	....	....	....	....
		201-500	14	369	5,162	5,162	62	3,223	28	1,939	....	....	....	....
		501 and above	26	1,650	43,103	43,103	484	34,090	79	9,013	....	....	....	....
			128	420	53,625	53,625	733	41,368	153	12,257	....	....	....	....
	Purchased electric power only:	1-200	17	43	726	....	....	....	....	....	....	....	....	....
		201-500	2	313	625	....	....	....	....	....	....	....	....	....
			19	72	1,351	....	....	....	....	....	....	....	....	....
	All other power:	1-200	34	74	2,533	1,767	44	811	28	876	6	66	1	14
		201-500	7	377	2,636	2,049	51	1,225	16	814	1	10	0	0
		501 and above	14	3,430	48,052	46,351	503	32,068	207	11,343	26	2,940	0	0
			55	970	53,221	50,167	598	34,104	251	13,033	33	3,016	1	14
	Total power		202	540	108,197	103,792	1,331	75,472	404	25,290	33	3,106	1	14
	Grand total		265	....	108,197	103,792	1,331	75,472	404	25,290	33	3,016	1	14
8d. Petroleum refining.	Steam power only:	1-200	1	75	75	75	7	73	1	2	....	....	....	....
		201-500	3	349	1,048	1,048	29	1,048	....	....	....	....	....	....
		501 and above	5	4,806	24,031	24,031	292	13,271	23	10,760	....	....	....	....
			9	2,795	25,154	25,154	328	14,392	24	10,762	....	....	....	....
	Purchased electric power only:	1-200	4	39	147	....	....	....	....	....	....	....	....	....
	All other power:	201-500	1	374	374	374	17	372	0	0	1	2	0	0
		501 and above	7	5,835	40,842	39,492	364	14,892	53	12,396	25	12,204	0	0
			8	5,152	41,216	39,866	381	15,264	53	12,396	26	12,206	0	0
	Total power		21	3,167	66,517	65,020	709	29,656	77	23,158	26	12,206	0	0

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).								
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.	Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
16	17	18	19	20	21	22	23	24	25	26	27
....	....	....	....	62	1,711	62	1,711	0	181,066	181,066	0
....	....	....	....	356	12,641	356	12,641	3,113	1,431,323	1,434,122	36,945
....	....	....	....	418	14,352	418	14,352	3,113	1,612,389	1,615,188	36,945
12,765	316	12,765	....	316	12,765	....	....	500	1,406,938	1,407,388	0
6,249	154	6,249	0	213	7,124	59	875	464	1,000,443	1,000,860	0
19,014	470	19,014	0	947	34,241	477	15,227	4,077	4,019,770	4,023,436	36,945
....	....	....	....	0	0	0	0	792	0	713	0
....	....	....	....	328	1,431	328	1,431	9,543	57,983	66,533	0
....	....	....	....	670	11,068	670	11,068	21,234	180,102	199,202	0
....	....	....	....	998	12,499	998	12,499	31,569	238,085	266,448	0
10	2	10	....	2	10	....	....	0	10	10	0
620	42	620	....	42	620	....	....	2,135	45	1,955	0
2,142	78	2,142	....	78	2,142	....	....	0	4,700	4,700	0
2,772	122	2,772	....	122	2,772	....	....	2,135	4,755	6,665	0
161	9	161	0	9	161	0	0	226	0	203	0
321	13	321	0	14	336	1	15	6,119	5,000	10,500	0
219	11	219	0	46	807	35	588	108	3,576	3,673	0
701	33	701	0	69	1,304	36	603	6,453	8,576	14,376	0
3,473	155	3,473	0	1,189	16,575	1,034	13,102	40,157	251,416	287,489	0
....	....	....	....	....	....	....	....	61,526	225,348	280,548	3,146
....	....	....	....	53	819	53	819	79,958	109,818	180,616	17,611
....	....	....	....	21	210	21	210	68,757	96,096	157,896	7,938
....	....	....	....	296	4,000	296	4,000	423,775	1,045,529	1,425,529	228,741
....	....	....	....	370	5,029	370	5,029	572,490	1,250,443	1,764,041	254,290
726	55	726	....	55	726	....	....	10,798	95,521	105,121	26,125
625	31	625	....	31	625	....	....	8,652	149,341	157,091	1,810
1,351	86	1,351	....	86	1,351	....	....	19,450	244,862	262,212	27,935
766	54	753	13	79	1,008	25	255	46,742	98,952	140,952	10,634
587	48	587	0	48	587	0	0	753	170,413	171,090	1,427
1,701	225	1,701	0	420	4,900	195	3,199	528,141	409,365	883,365	311,197
3,054	327	3,041	13	547	6,495	220	3,454	575,636	678,730	1,195,407	323,258
4,405	413	4,392	13	1,003	12,875	590	8,483	1,167,576	2,174,035	3,221,660	605,483
4,405	413	4,392	13	1,003	12,875	590	8,483	1,229,102	2,399,383	3,502,208	608,629
....	....	....	....	5	21	5	21	0	0	0	0
....	....	....	....	104	1,204	104	1,204	11,062	69,536	79,492	0
....	....	....	....	231	4,936	231	4,936	395,366	122,396	478,225	44,479
....	....	....	....	340	6,161	340	6,161	406,428	191,932	557,717	44,479
147	19	147	....	19	147	....	....	0	0	0	0
0	0	0	0	0	0	0	0	6,000	3,000	8,400	0
1,350	29	1,350	0	766	19,333	737	17,983	625,225	193,981	756,683	177,677
1,350	29	1,350	0	766	19,333	737	17,983	631,225	196,981	765,083	177,677
1,497	48	1,497	0	1,125	25,641	1,077	24,144	1,037,653	388,913	1,322,800	222,156

TABLE 46.—*Mechanical power-supply equipment and fuel used.*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
			Number.	Average size (horsepower).	Aggregate horsepower.	Prime movers.								
						Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8c. All other chemicals.	No power		1,084	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	344	63	21,714	21,714	497	21,620	7	94	....	....	....	....
		201-500	69	328	22,756	22,756	198	20,656	11	2,100	....	....	....	....
		501 and above	53	1,480	78,476	78,476	379	49,196	81	29,280	....	....	....	....
			466	262	122,946	122,946	1,074	91,472	99	31,474	....	....	....	....
	Purchased electric power only:	1-200	943	22	20,788	....	....	....	....	....	....	....	....	....
		201-500	41	312	12,805	....	....	....	....	....	....	....	....	....
		501 and above	19	1,180	22,488	....	....	....	....	....	....	....	....	....
			1,003	56	56,081	....	....	....	....	....	....	....	....	....
	All other power:	1-200	281	52	14,674	9,194	187	6,225	7	346	134	2,237	16	386
		201-500	49	321	15,733	9,698	121	8,028	2	225	26	615	8	830
		501 and above	54	1,490	80,433	43,127	459	30,824	21	8,697	30	2,017	13	1,589
			384	288	110,840	62,919	767	45,077	30	9,268	190	4,869	37	2,805
		Total power	1,853	155	289,867	184,965	1,841	136,549	129	40,742	190	4,869	37	2,805
		Grand total	2,937	....	289,867	184,965	1,841	136,549	129	40,742	190	4,869	37	2,805
9a. Cement.	No power		1	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	201-500	1	400	400	400	0	0	0	400	....	....	....	....
		501 and above	8	7,090	56,750	56,750	113	54,000	2	2,750	....	....	....	....
			9	6,350	57,150	57,150	113	54,000	4	3,150	....	....	....	....
	Purchased electric power only:	1-200	3	72	216	....	....	....	....	....	....	....	....	....
		501 and above	8	4,141	33,127	....	....	....	....	....	....	....	....	....
			11	3,031	33,343	....	....	....	....	....	....	....	....	....
	All other power:	501 and above	8	8,947	71,573	57,736	79	40,694	9	10,920	15	6,072	1	50
		Total power	28	5,800	162,066	114,886	192	94,694	13	14,070	15	6,072	1	50
		Grand total	29	....	162,066	114,886	192	94,694	13	14,070	15	6,072	1	50
9b. All other stone products.	No power		467	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	120	74	8,796	8,796	198	8,781	1	15	....	....	....	....
		201-500	23	303	6,951	6,951	76	6,801	1	150	....	....	....	....
		501 and above	6	690	4,130	4,130	46	3,980	1	150	....	....	....	....
			149	132	19,877	19,877	320	19,562	3	315	....	....	....	....
	Purchased electric power only:	1-200	648	20	12,733	....	....	....	....	....	....	....	....	....
		201-500	9	330	2,973	....	....	....	....	....	....	....	....	....
		501 and above	4	1,212	4,847	....	....	....	....	....	....	....	....	....
			661	31	20,553	....	....	....	....	....	....	....	....	....
	All other power:	1-200	407	29	11,726	8,450	112	4,602	0	0	355	3,746	5	102
		201-500	28	301	8,438	4,902	74	4,328	0	0	46	354	1	220
		501 and above	12	1,310	15,710	8,122	183	6,453	2	1,667	1	2	0	0
			447	80	35,814	21,474	369	15,383	2	1,667	402	4,102	6	322
		Total power	1,257	60	76,304	41,351	689	34,945	5	1,982	402	4,102	6	322
		Grand total	1,724	....	76,304	41,351	689	34,945	5	1,982	402	4,102	6	322

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
....	....	....	....	....	....	....	....	17,747	38,978	54,953	327
....	....	....	....	466	4,867	466	4,867	88,393	186,889	266,443	6,072
....	....	....	....	1,192	12,562	1,192	12,562	60,491	190,625	245,066	5,364
....	....	....	....	5,309	63,872	5,309	63,872	304,617	736,776	1,010,933	10,509
....	....	....	....	6,967	81,301	6,967	81,301	453,501	1,114,290	1,522,442	21,945
20,788	3,459	20,788	....	3,459	20,788	....	....	123,834	87,017	198,468	3,597
12,805	1,083	12,805	....	1,083	12,805	....	....	9,016	47,344	55,458	1,648
22,488	1,172	22,488	....	1,172	22,488	....	....	14,180	86,066	98,828	180
56,081	5,714	56,081	....	5,714	56,081	....	....	147,030	220,427	352,754	5,425
5,480	779	4,869	611	914	5,636	135	767	53,270	69,402	117,345	2,595
6,035	580	6,035	0	841	8,577	261	2,542	71,528	67,974	132,351	3,593
37,306	2,455	37,306	0	3,510	49,691	1,055	12,385	250,121	445,742	670,850	5,955
48,821	3,814	48,210	611	5,265	63,904	1,451	15,694	374,919	583,118	920,546	12,143
104,902	9,528	104,291	611	17,946	201,286	8,418	96,995	975,450	1,917,835	2,795,742	39,513
104,902	9,528	104,291	611	17,946	201,286	8,418	96,995	993,197	1,956,813	2,850,695	39,840
....	....	....	....	....	....	....	....	42	128	165	0
....	....	....	....	25	500	25	500	0	7,436	7,436	0
....	....	....	....	836	26,271	836	26,271	214,422	810,711	1,003,711	0
....	....	....	....	861	26,771	861	26,771	214,422	818,147	1,011,147	00
216	16	216	....	16	216	....	....	0	0	0	120
33,127	610	33,127	....	610	33,127	....	....	7,370	285,379	292,009	1,466
33,343	626	33,343	....	626	33,343	....	....	7,370	285,379	292,009	1,586
13,837	211	13,837	0	499	28,128	288	14,291	50,407	750,867	796,167	0
47,180	837	47,180	0	1,986	88,242	1,149	41,062	272,199	1,854,393	2,099,323	1,586
47,180	837	47,180	0	1,986	88,242	1,149	41,062	272,241	1,854,521	2,099,488	1,586
....	....	....	....	....	....	....	....	7,510	17,361	24,111	2,065
....	....	....	....	36	500	36	500	16,758	27,468	42,468	3,861
....	....	....	....	146	1,845	146	1,845	18,648	21,277	37,977	0
....	....	....	....	48	1,653	48	1,653	7,865	22,885	29,935	30,900
....	....	....	....	230	3,998	230	3,998	43,271	71,630	110,380	34,761
12,733	1,157	12,733	....	1,157	12,733	....	....	5,388	13,311	18,141	3,921
2,973	209	2,973	....	209	2,973	....	....	1,400	25,100	26,360	0
4,847	190	4,847	....	190	4,847	....	....	215	21,599	21,792	0
20,553	1,556	20,553	....	1,556	20,553	....	....	7,003	60,010	66,293	3,921
3,276	219	2,937	339	249	2,357	30	320	13,133	33,830	45,630	3,259
3,536	172	3,536	0	203	3,984	31	448	3,511	35,937	39,097	50
7,588	369	7,588	0	429	8,938	60	1,350	21,758	65,141	84,841	9,382
14,400	760	14,061	339	881	16,179	121	2,118	38,402	134,908	169,368	12,691
34,953	2,316	34,614	339	2,667	40,730	351	6,116	88,676	266,548	346,041	51,373
34,953	2,316	34,614	339	2,667	40,730	351	6,116	96,186	283,909	370,152	53,438

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
			Number.	Average size (horsepower).	Aggregate horsepower.	Prime movers.								
						Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
9c. All clay products.	No power		101	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	192	84	16,158	16,156	242	16,078	2	80	....	....	....	....
		201-500	41	329	13,476	13,476	109	13,476	0	0	....	....	....	....
		501 and above	15	882	13,250	13,250	66	12,500	1	750	....	....	....	....
			248	180	42,884	42,884	417	42,054	3	830	....	....	....	....
	Purchased electric power only:	1-200	160	52	8,315	....	....	....	....	....	....	....	....	....
		201-500	25	233	5,826	....	....	....	....	....	....	....	....	....
		501 and above	3	860	2,580	....	....	....	....	....	....	....	....	....
			188	89	16,721	....	....	....	....	....	....	....	....	....
	All other power:	1-200	95	87	8,256	6,464	67	4,475	0	0	53	1,034	18	955
		201-500	46	298	13,712	10,472	97	8,117	2	295	22	633	13	1,427
		501 and above	16	750	12,029	7,472	65	6,904	0	0	13	238	2	330
			157	216	33,997	24,408	229	19,496	2	295	88	1,905	33	2,712
	Total power		593	168	93,602	67,292	646	61,550	5	1,125	88	1,905	33	2,712
	Grand total		694	....	93,602	67,292	646	61,550	5	1,125	88	1,905	33	2,712
9d. All glass products.	No power		109	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	27	66	1,766	1,766	31	1,566	2	200	....	....	....	....
		201-500	2	305	610	610	7	610	0	0	....	....	....	....
		501 and above	1	885	885	885	17	885	0	0	....	....	....	....
			30	109	3,261	3,261	55	3,061	2	200	....	....	....	....
	Purchased electric power only:	1-200	232	9	2,191	....	....	....	....	....	....	....	....	....
		201-500	5	352	1,760	....	....	....	....	....	....	....	....	....
		501 and above	2	632	1,263	....	....	....	....	....	....	....	....	....
			239	22	5,214	....	....	....	....	....	....	....	....	....
	All other power:	1-200	51	36	1,831	1,096	16	429	0	0	33	627	2	40
		201-500	4	248	993	220	4	220	0	0	0	0	0	0
		501 and above	2	874	1,747	1,245	2	45	0	0	3	1,200	0	0
			57	80	4,571	2,561	22	694	0	0	36	1,827	2	40
	Total power		326	40	13,046	5,822	77	3,755	2	200	36	1,827	2	40
	Grand total		435	....	13,046	5,822	77	3,755	2	200	36	1,827	2	40
10a. Metals other than iron and steel.	No power		90	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	33	65	2,143	2,143	38	2,143	0	0	....	....	....	....
		201-500	6	327	1,963	1,963	11	1,963	0	0	....	....	....	....
		501 and above	14	10,300	144,708	144,708	117	62,630	60	82,078	....	....	....	....
			53	2,800	148,814	148,814	166	66,736	60	82,078	....	....	....	....
	Purchased electric power only:	1-200	372	24	8,884	....	....	....	....	....	....	....	....	....
		201-500	15	310	4,654	....	....	....	....	....	....	....	....	....
		501 and above	11	2,103	23,136	....	....	....	....	....	....	....	....	....
			398	92	36,674	....	....	....	....	....	....	....	....	....
	All other power:	1-200	119	24	2,854	1,655	6	305	1	10	84	1,310	3	30
		201-500	11	348	3,831	2,165	11	1,405	0	0	3	500	5	260
		501 and above	25	4,201	105,036	43,192	103	29,245	10	11,267	4	650	13	2,030
			155	720	111,721	47,012	120	30,955	11	11,277	91	2,460	21	2,320
	Total power		606	490	297,209	195,826	286	97,691	71	93,355	91	2,460	21	2,320
	Grand total		696	....	297,209	195,826	286	97,691	71	93,355	91	2,460	21	2,320

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).	Number.	Horsepower.	Number.	Horsepower.	Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.									
16	17	18	19	20	21	22	23	24	25	26	27
....	....	....	....	....	....	....	....	3,879	12,493	16,003	144
....	....	....	....	60	506	60	506	40,566	174,129	210,652	940
....	....	....	....	140	2,167	140	2,167	19,724	94,358	112,109	1,049
....	....	....	....	144	3,992	144	3,992	38,424	64,395	98,973	138
....	....	....	....	344	6,665	344	6,665	98,714	332,882	421,734	2,127
8,315	537	8,315	....	537	8,315	....	....	13,094	57,225	69,010	349
5,826	131	5,826	....	131	5,826	....	....	2,818	44,588	46,408	372
2,580	86	2,580	....	86	2,580	....	....	45	19,228	19,268	340
16,721	754	16,721	....	754	16,721	....	....	15,957	121,041	134,686	1,061
1,792	153	1,745	47	153	1,745	0	0	24,121	46,063	67,771	2,171
3,240	167	3,240	0	204	3,865	37	625	11,553	102,304	112,699	750
4,557	198	4,557	0	273	5,049	75	492	22,068	123,455	143,316	369
9,589	518	9,542	47	630	10,659	112	1,117	57,742	271,822	323,786	3,290
26,310	1,272	26,263	47	1,728	34,045	456	7,782	172,413	725,745	880,206	6,478
26,310	1,272	26,263	47	1,728	34,045	456	7,782	176,312	738,238	896,209	6,622
....	....	....	....	....	....	....	....	231	55	262	125
....	....	....	....	39	239	39	239	5,396	46,479	51,329	889
....	....	....	....	44	392	44	392	0	17,111	17,111	0
....	....	....	....	25	168	25	168	239	37,768	37,398	0
....	....	....	....	108	799	108	799	5,635	101,358	106,423	889
2,191	576	2,191	....	576	2,191	....	....	2,951	13,143	15,793	285
1,760	138	1,760	....	138	1,760	....	....	....	36,951	36,951	0
1,263	31	1,263	....	31	1,263	....	....	40	4,732	4,769	0
5,214	745	5,214	....	745	5,214	....	....	2,991	54,826	57,513	285
735	95	639	96	111	765	16	126	3,091	26,223	29,008	5,092
773	43	773	0	43	773	0	0	297	5,864	6,131	200
502	39	502	0	130	1,966	91	1,464	0	42,847	42,847	0
2,010	177	1,914	96	284	3,504	107	1,590	3,388	74,934	77,981	5,292
7,224	922	7,128	96	1,137	9,517	215	2,389	12,014	231,118	241,917	6,466
7,224	922	7,128	96	1,137	9,517	215	2,389	12,245	231,173	242,179	6,591
....	....	....	....	....	....	....	....	2,737	2,892	5,252	944
....	....	....	....	63	764	63	764	6,157	9,149	14,649	1,764
....	....	....	....	55	993	55	993	773	10,137	10,832	2,880
....	....	....	....	3,685	66,628	3,685	66,628	621,618	613,713	1,173,713	155,913
....	....	....	....	3,803	68,385	3,803	68,385	628,548	632,999	1,199,194	160,557
8,884	1,287	8,884	....	1,287	8,884	....	....	21,164	20,008	39,008	117,034
4,654	631	4,654	....	631	4,654	....	....	1,848	5,034	6,694	1,790
23,136	1,003	23,136	....	1,003	23,136	....	....	27,009	12,271	56,571	1,253
36,674	2,921	36,674	....	2,921	36,674	....	....	50,021	37,313	82,273	120,077
1,199	81	761	438	83	762	2	1	4,725	10,115	14,365	5,061
1,666	133	1,666	0	165	2,002	32	336	2,036	15,289	17,129	5,627
61,844	2,412	48,159	13,685	2,944	62,640	532	14,481	108,408	281,089	378,589	37,129
64,709	2,626	50,586	14,123	3,192	65,404	566	14,818	115,169	306,493	410,083	47,817
101,383	5,547	87,260	14,123	9,916	170,463	4,369	83,203	793,738	976,805	1,691,550	328,451
101,383	5,547	87,260	14,123	9,916	170,463	4,369	83,203	796,475	979,697	1,696,803	329,395

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
			Number.	Average size (horsepower).	Aggregate horsepower.	Prime movers.								
						Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
10b. Metal products other than iron and steel.	No power		1,174	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:													
		1-200	68	77	5,235	5,235	75	5,160	1	75	....	....	....	....
		201-500	16	298	4,769	4,769	27	3,941	8	828	....	....	....	....
		501 and above	8	774	6,196	6,196	29	6,196	0	0	....	....	....	....
			92	176	16,200	16,200	131	15,297	9	903	....	....	....	....
	Purchased electric power only:													
		1-200	2,163	12	26,618	....	....	....	....	....	....	....	....	....
		201-500	22	272	5,992	....	....	....	....	....	....	....	....	....
		501 and above	8	830	6,039	....	....	....	....	....	....	....	....	....
			2,193	18	39,249	....	....	....	....	....	....	....	....	....
	All other power:													
		1-200	485	27	13,223	8,442	62	4,207	4	225	194	3,399	20	611
		201-500	20	296	5,925	3,695	29	2,733	0	0	1	55	13	907
		501 and above	27	1,240	33,443	21,611	63	16,338	4	3,098	5	1,020	18	1,155
			532	99	52,591	33,748	154	23,278	8	3,323	200	4,474	51	2,673
	Total power		2,817	383	108,040	49,948	285	38,575	17	4,226	200	4,474	51	2,673
	Grand total		3,991	....	108,040	49,948	285	38,575	17	4,226	200	4,474	51	2,673
11. Tobacco manufactures.	No power		3,608	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:													
		1-200	32	67	2,135	2,135	41	2,135	0	0	....	....	....	....
		201-500	3	222	666	666	9	666	0	0	....	....	....	....
		501 and above	2	940	1,880	1,880	7	1,880	0	0	....	....	....	....
			37	127	4,681	4,681	57	4,681	0	0	....	....	....	....
	Purchased electric power only:													
		1-200	480	8	3,638	....	....	....	....	....	....	....	....	....
		201-500	3	387	1,162	....	....	....	....	....	....	....	....	....
			483	10	4,800	....	....	....	....	....	....	....	....	....
	All other power:													
		1-200	39	56	2,169	1,744	24	1,368	1	40	17	176	3	160
		201-500	5	279	1,396	645	7	545	0	0	0	0	4	100
		501 and above	3	763	2,288	1,703	19	1,150	1	536	0	0	1	17
			47	124	5,853	4,092	50	3,063	2	576	17	176	8	277
	Total power		567	27	15,334	8,773	107	7,744	2	576	17	176	8	277
	Grand total		4,175	....	15,334	8,773	107	7,744	2	576	17	176	8	277
12a. Automobiles.	No power		257	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:													
		1-200	25	46	1,115	1,115	21	1,115	0	0	....	....	....	....
		201-500	4	338	1,350	1,350	8	1,200	1	150	....	....	....	....
		501 and above	5	1,375	6,875	6,875	11	3,375	3	3,500	....	....	....	....
			34	273	9,340	9,340	40	5,690	4	3,650	....	....	....	....
	Purchased electric power only:													
		1-200	2,770	7	19,899	....	....	....	....	....	....	....	....	....
		201-500	12	331	3,966	....	....	....	....	....	....	....	....	....
		501 and above	8	1,624	12,993	....	....	....	....	....	....	....	....	....
			2,790	13	36,858	....	....	....	....	....	....	....	....	....
	All other power:													
		1-200	378	11	4,264	3,629	24	1,065	0	0	365	2,368	4	196
		201-500	5	281	1,407	855	6	615	0	0	2	240	0	0
		501 and above	7	919	6,438	2,270	12	1,880	2	225	1	165	0	0
			390	31	12,109	6,754	42	3,560	2	225	368	2,773	4	196
	Total power		3,214	18	58,307	16,094	82	9,250	6	3,875	368	2,773	4	196
	Grand total		3,471	....	58,307	16,094	82	9,250	6	3,875	368	2,773	4	196

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).	Number.	Horsepower.	Number.	Horse power.	Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.									
16	17	18	19	20	21	22	23	24	25	26	27
....	....	....	....	....	....	....	....	2,350	899	3,014	817
....	....	....	....	317	2,039	317	2,039	11,370	21,267	31,500	2,094
....	....	....	....	577	2,954	577	2,954	8,956	15,257	23,322	43
....	....	....	....	577	7,958	577	7,958	14,737	29,630	42,896	734
....	....	....	....	1,471	12,951	1,471	12,951	35,063	66,154	97,718	2,871
26,618	7,384	26,618	....	7,384	26,618	....	....	13,100	15,314	27,104	3,564
5,992	617	5,992	....	617	5,992	....	....	388	6,726	7,075	192
6,639	613	6,639	....	613	6,639	....	....	1,978	5,428	7,210	0
39,249	8,614	39,249	....	8,614	39,249	....	....	15,466	27,468	41,389	3,756
4,781	350	2,567	2,214	900	4,901	550	2,334	5,510	30,135	35,094	1,627
2,230	291	1,980	250	485	3,543	194	1,563	3,848	17,727	21,195	0
11,832	1,908	11,832	0	3,307	22,640	1,399	10,808	25,149	84,421	107,156	766
18,843	2,549	16,379	2,464	4,692	31,084	2,143	14,705	34,507	132,283	163,445	2,393
58,092	11,163	55,628	2,464	14,777	83,284	3,614	27,656	85,036	225,905	302,552	9,020
58,092	11,163	55,628	2,464	14,777	83,284	3,614	27,656	87,386	226,804	305,566	9,837
....	....	....	....	....	....	....	....	8,198	2,513	9,863	10
....	....	....	....	107	598	107	598	5,914	4,373	9,693	58
....	....	....	....	9	240	9	240	890	4,652	5,442	0
....	....	....	....	99	1,386	99	1,386	46	13,996	14,037	180
....	....	....	....	215	2,224	215	2,224	6,850	23,021	29,172	238
3,638	1,274	3,638	....	1,274	3,638	....	....	11,206	4,878	14,978	482
1,162	74	1,162	....	74	1,162	....	....	299	400	668	0
4,800	1,348	4,800	....	1,348	4,800	....	....	11,505	5,278	15,646	482
425	94	425	0	155	872	61	447	6,073	2,927	8,477	0
751	263	751	0	294	999	31	248	2,212	1,235	3,225	0
585	40	585	0	40	585	0	0	4,691	5,033	9,233	178
1,761	397	1,761	0	489	2,456	92	695	12,976	9,195	20,935	178
6,561	1,745	6,561	0	2,052	9,480	307	2,919	31,331	37,494	65,753	898
6,561	1,745	6,561	0	2,052	9,480	307	2,919	39,529	40,007	75,616	908
....	....	....	....	....	....	....	....	1,291	384	1,549	0
....	....	....	....	79	489	79	489	1,561	8,199	9,603	0
....	....	....	....	16	121	16	121	2,113	3,996	5,900	0
....	....	....	....	348	4,590	348	4,590	3,659	27,690	30,983	0
....	....	....	....	443	5,200	443	5,200	7,333	39,885	46,486	0
19,899	5,645	19,899	....	5,645	19,899	....	....	26,771	23,937	48,030	488
3,966	449	3,966	....	449	3,966	....	....	3,418	3,098	6,175	2
12,993	1,746	12,993	....	1,746	12,993	....	....	14,772	24,940	38,233	580
36,858	7,840	36,858	....	7,840	36,858	....	....	44,961	51,975	92,438	1,070
635	162	554	81	202	754	40	200	3,065	4,761	7,520	91
552	84	552	0	91	588	7	36	850	3,095	3,860	50
4,168	367	4,168	0	490	5,016	123	848	902	18,425	19,237	2
5,355	613	5,274	81	783	6,358	170	1,084	4,817	26,281	30,617	143
42,213	8,453	42,132	81	9,066	48,416	613	6,284	57,111	118,141	169,541	1,213
42,213	8,453	42,132	81	9,066	48,416	613	6,284	58,402	118,525	171,090	1,213

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
			Number.	Average size (horsepower).	Aggregate horsepower.	Prime movers.								
						Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
12b. Cars not by railroads.	Steam power only:	1-200	2	110	220	220	3	220	0	0	......	......	......	......
		201-500	1	350	350	350	2	350	0	0	......	......	......	......
			3	190	570	570	5	570	0	0	......	......	......	......
	Purchased electric power only:	501 and above	2	2,772	5,543	......	......	......	......	......	......	......	......	......
	All other power:	501 and above	6	2,752	16,515	4,828	14	4,320	1	500	2	8	0	0
		Total power	11	2,057	22,628	5,398	19	4,890	1	500	2	8	0	0
12c. All other vehicles.	No power		186	......	......	......	......	......	......	......	......	......	......	......
	Steam power only:	1-200	30	48	1,431	1,431	27	1,375	2	56	......	......	......	......
		201-500	1	300	300	300	1	300	0	0	......	......	......	......
			31	56	1,731	1,731	28	1,675	2	56	......	......	......	......
	Purchased electric power only:	1-200	450	8	3,618	......	......	......	......	......	......	......	......	......
		201-500	1	395	395	......	......	......	......	......	......	......	......	......
		501 and above	1	2,074	2,074	......	......	......	......	......	......	......	......	......
			452	13	6,087	......	......	......	......	......	......	......	......	......
	All other power:	1-200	148	20	3,017	2,509	16	795	0	0	128	1,083	18	631
		201-500	4	348	1,390	1,290	5	775	0	0	0	0	9	515
		501 and above	2	1,110	2,220	1,200	4	1,200	0	0	0	0	0	0
			154	43	6,627	4,999	25	2,770	0	0	128	1,083	27	1,146
		Total power	637	23	14,445	6,730	53	4,445	2	56	128	1,083	27	1,146
		Grand total	823	......	14,445	6,730	53	4,445	2	56	128	1,083	27	1,146
13a. Steam railroad repair shops.	No power		26	......	......	......	......	......	......	......	......	......	......	......
	Steam power only:	1-200	40	62	2,496	2,496	56	2,446	1	50	......	......	......	......
		201-500	12	293	3,521	3,521	33	3,521	0	0	......	......	......	......
		501 and above	25	1,960	49,006	49,006	182	43,456	10	5,550	......	......	......	......
			77	715	55,023	55,023	271	49,423	11	5,600	......	......	......	......
	Purchased electric power only:	1-200	50	59	2,974	......	......	......	......	......	......	......	......	......
		201-500	8	259	2,075	......	......	......	......	......	......	......	......	......
		501 and above	7	1,034	7,238	......	......	......	......	......	......	......	......	......
			65	189	12,287	......	......	......	......	......	......	......	......	......
	All other power:	1-200	27	102	2,748	1,728	26	1,521	0	0	16	207	0	0
		201-500	5	383	1,915	660	7	660	0	0	0	0	0	0
		501 and above	15	1,880	28,371	10,333	62	9,537	3	550	6	151	2	95
			47	702	33, 034	12,721	95	11,718	3	550	22	358	2	95
		Total power	189	530	100,344	67,744	366	61,141	14	6,150	22	358	2	95
		Grand total	215	......	100,344	67,744	366	61,141	14	6,150	22	358	2	95

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).	Number.	Horsepower.	Number.	Horse power.	Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.									
16	17	18	19	20	21	22	23	24	25	26	27
....	....	....	....	50	200	50	200	384	700	1,044	0
....	....	....	....	15	231	15	231	3	5,574	5,574	30
....	....	....	....	65	431	65	431	387	6,274	6,618	30
5,543	340	5,543	....	340	5,543	....	....	232	7,838	8,046	282
11,687	689	11,687	0	1,593	20,792	904	9,105	37,852	68,816	102,816	8,432
17,230	1,029	17,230	0	1,998	26,766	969	9,536	38,471	82,928	117,480	8,744
....	....	....	....	....	....	....	....	304	1,129	1,403	11
....	....	....	....	7	148	7	148	2,134	4,328	6,238	428
....	....	....	....	0	0	0	0	0	991	991	0
....	....	....	....	7	148	7	148	2,134	5,319	7,229	428
3,618	1,083	3,618	....	1,083	3,618	....	....	2,486	5,531	7,771	41
395	27	395	....	27	395	....	....	5	1,400	1,405	0
2,074	130	2,074	....	130	2,074	....	....	4,280	2,392	6,242	0
6,087	1,240	6,087	....	1,240	6,087	....	....	6,771	9,323	15,418	41
508	98	425	83	127	627	29	202	1,227	4,996	6,096	67
100	3	100	0	4	101	1	1	0	1,604	1,604	75
1,020	69	1,020	0	77	1,280	8	280	360	4,461	4,785	0
1,628	170	1,545	83	208	2,008	38	463	1,587	11,061	12,485	142
7,715	1,410	7,632	83	1,455	8,243	45	611	10,492	25,703	35,132	611
7,715	1,410	7,632	83	1,455	8,243	45	611	10,795	26,832	36,535	622
....	....	....	....	....	....	....	....	737	4,115	4,778	0
....	....	....	....	65	1,442	65	1,442	17,838	57,310	73,360	0
....	....	....	....	182	3,932	182	3,932	38,690	43,623	78,444	0
....	....	....	....	3,013	41,309	3,013	41,309	245,406	226,354	447,220	202,313
....	....	....	....	3,260	46,683	3,260	46,683	301,934	327,287	599,024	202,313
2,974	240	2,974	....	240	2,974	....	....	3,240	46,311	49,227	9
2,075	106	2,075	....	106	2,075	....	....	2,056	5,018	6,870	0
7,238	268	7,238	....	268	7,238	....	....	14,534	65,035	78,116	294
12,287	614	12,287	....	614	12,287	....	....	19,830	116,364	134,213	303
1,020	50	670	350	59	815	3	145	11,986	44,300	55,088	0
1,255	51	1,005	250	51	1,005	0	0	1,321	4,853	6,042	253
18,038	962	18,038	0	1,059	20,056	97	2,018	85,897	108,024	180,332	2,216
20,313	1,069	19,713	600	1,169	21,876	100	2,163	99,204	152,177	241,462	2,469
32,600	1,683	32,000	600	5,043	80,846	3,360	48,846	420,968	595,828	974,699	205,085
32,600	1,683	32,000	600	5,043	80,846	3,360	48,846	421,705	599,943	979,477	205,085

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
			Number.	Average size (horsepower).	Aggregate horsepower.	Prime movers.								
						Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
13b. Electric railroad repair shops.	No power		27	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	7	41	285	285	13	285	0	0	....	....	....	....
		201-500	1	400	400	400	2	400	0	0	....	....	....	....
			8	86	685	685	15	685	0	0	....	....	....	....
	Purchased electric power only:	1-200	101	94	9,485	....	....	....	....	....	....	....	....	....
		201-500	11	360	3,954	....	....	....	....	....	....	....	....	....
		501 and above	4	1,171	4,683	....	....	....	....	....	....	....	....	....
			116	156	18,122	....	....	....	....	....	....	....	....	....
	All other power:	1-200	2	65	130	100	1	100	0	0	0	0	0	0
		501 and above	1	625	625	20	2	20	0	0	0	0	0	0
			3	252	755	120	3	120	0	0	0	0	0	0
	Total power		127	153	19,562	805	18	805	0	0	0	0	0	0
	Grand total		154	....	19,562	805	18	805	0	0	0	0	0	0
14a. Miscellaneous metal products.	No power		56	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	23	84	1,942	1,942	26	1,942	0	0	....	....	....	....
		201-500	6	304	1,825	1,825	9	1,825	0	0	....	....	....	....
		501 and above	3	2,373	7,121	7,121	5	1,100	5	6,021	....	....	....	....
			32	34	10,888	10,888	40	4,867	5	6,021	....	....	....	....
	Purchased electric power only:	1-200	393	15	5,958	....	....	....	....	....	....	....	....	....
		201-500	6	285	1,712	....	....	....	....	....	....	....	....	....
		501 and above	4	1,378	5,510	....	....	....	....	....	....	....	....	....
			403	33	13,180	....	....	....	....	....	....	....	....	....
	All other power:	1-200	73	41	2,995	2,293	12	734	0	0	48	664	19	895
		201-500	7	295	2,068	1,240	11	605	0	0	4	475	2	160
		501 and above	9	3,517	31,652	19,334	50	6,212	24	10,382	10	2,093	3	647
			89	412	36,715	22,867	73	7,551	24	10,382	62	3,232	24	1,702
	Total power		524	116	60,783	33,755	113	12,418	29	16,403	62	3,232	24	1,702
	Grand total		580	....	60,783	33,755	113	12,418	29	16,403	62	3,232	24	1,702
14b. Rubber goods.	No power		7	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	15	127	1,915	1,915	19	1,915	0	0	....	....	....	....
		201-500	17	321	5,788	5,788	35	5,788	0	0	....	....	....	....
		501 and above	20	1,606	32,127	32,127	55	20,803	12	11,324	....	....	....	....
			52	765	39,830	39,830	109	28,506	12	11,324	....	....	....	....
	Purchased electric power only:	1-200	55	42	2,333	....	....	....	....	....	....	....	....	....
		201-500	11	316	3,482	....	....	....	....	....	....	....	....	....
		501 and above	11	2,553	28,089	....	....	....	....	....	....	....	....	....
			77	440	33,904	....	....	....	....	....	....	....	....	....
	All other power:	1-200	19	105	2,008	1,215	12	800	0	0	3	200	2	215
		201-500	20	313	6,257	4,331	28	3,870	0	0	1	6	6	455
		501 and above	49	1,890	93,121	42,691	124	36,369	15	2,740	3	817	20	2,765
			88	1,140	101,386	48,237	164	41,039	15	2,740	7	1,023	28	3,435
	Total power		217	1,500	175,120	88,067	273	69,545	27	14,064	7	1,023	28	3,435
	Grand total		224	....	175,120	88,067	273	69,545	27	14,064	7	1,023	28	3,435

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).	Number.	Horsepower.	Number.	Horsepower.	Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.									
16	17	18	19	20	21	22	23	24	25	26	27
...	...	...	...	...	...	...	...	782	304	1,006	1
...	...	...	...	0	0	0	0	30	581	608	0
...	...	...	...	0	0	0	0	0	4,397	4,397	0
...	...	...	...	0	0	0	0	30	4,978	5,005	0
9,485	584	9,485	...	584	9,485	...	...	6,040	9,641	15,071	0
3,954	219	3,954	...	219	3,954	...	...	1,896	1,564	3,264	0
4,683	256	4,683	...	256	4,683	...	...	5,393	530	5,380	0
18,122	1,059	18,122	...	1,059	18,122	...	...	13,329	11,735	23,715	0
30	1	5	25	1	5	0	0	20	0	18	0
605	20	605	0	20	605	0	0	0	13,422	13,422	0
635	21	610	25	21	610	0	0	20	13,422	13,440	0
18,757	1,080	18,732	25	1,080	18,732	0	0	13,379	30,135	42,160	0
18,757	1,080	18,732	25	1,080	18,732	0	0	14,161	30,439	43,166	1
...	...	...	...	...	...	...	...	190	199	370	0
...	...	...	...	212	545	212	545	3,019	4,969	7,687	711
...	...	...	...	66	364	66	364	2,732	1,693	4,180	0
...	...	...	...	378	1,560	378	1,560	3,716	24,200	27,548	0
...	...	...	...	656	2,469	656	2,469	9,467	30,062	39,415	711
5,958	1,841	5,958	...	1,841	5,958	...	...	6,461	6,835	12,649	133
1,712	166	1,712	...	166	1,712	...	...	968	3,197	4,070	0
5,510	502	5,510	...	502	5,510	...	...	80	9,084	9,156	0
13,180	2,509	13,180	...	2,509	13,180	...	...	7,509	19,116	25,875	133
702	102	561	141	158	794	56	233	3,813	1,461	4,890	548
828	126	828	0	127	883	1	55	27,090	2,975	27,356	3,408
12,318	1,039	12,318	0	2,593	26,015	1,554	13,697	16,901	102,782	117,990	4,420
13,848	1,267	13,707	141	2,878	27,692	1,611	13,985	47,804	107,218	150,236	8,376
27,028	3,776	26,887	141	6,043	43,341	2,267	16,454	64,780	157,196	215,526	9,220
27,028	3,776	26,887	141	6,043	43,341	2,267	16,454	64,970	157,395	215,896	9,220
...	...	...	...	...	...	...	...	115	1,100	1,203	0
...	...	...	...	13	125	13	125	1,434	10,745	12,035	0
...	...	...	...	112	2,314	112	2,314	9,737	22,174	30,924	70
...	...	...	...	1,288	23,582	1,288	23,582	46,190	151,602	193,202	3,099
...	...	...	...	1,413	26,021	1,413	26,021	57,361	184,521	236,161	3,169
2,333	178	2,333	...	178	2,333	...	...	471	4,544	4,969	0
3,482	108	3,482	...	108	3,482	...	...	809	15,573	16,300	0
28,089	1,412	28,089	...	1,412	28,089	...	...	4,121	58,335	62,055	0
33,904	1,698	33,904	...	1,698	33,904	...	...	5,401	78,452	83,324	0
793	58	666	127	58	666	0	0	2,190	5,309	7,279	0
1,926	106	1,926	0	124	2,123	18	197	1,857	26,769	28,429	825
50,430	2,101	50,430	0	3,073	60,944	972	10,514	61,377	289,312	344,512	12
53,149	2,265	53,022	127	3,255	63,733	990	10,711	65,424	321,390	380,220	837
87,053	3,963	86,926	127	6,366	123,658	2,403	36,732	128,186	584,363	699,705	4,006
87,053	3,963	86,926	127	6,366	123,658	2,403	36,732	128,301	585,463	700,908	4,006

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments. Number.	Establishments. Average size (horsepower).	Power-supply equipment. Aggregate horsepower.	Prime movers. Total horsepower.	Steam engines. Number.	Steam engines. Horsepower.	Steam turbines. Number.	Steam turbines. Horsepower.	Internal-combustion engines. Number.	Internal-combustion engines. Horsepower.	Water wheels. Number.	Water wheels. Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
14c. Electrical machinery.	No power		30	......	......	......	......	......	......	......	......	......	......	......
	Steam power only:	1-200	8	67	542	542	8	542	0	0	......	......	......	......
		201-500	12	291	3,495	3,495	21	2,795	3	700	......	......	......	......
		501 and above	5	6,293	31,468	31,468	44	15,018	5	16,450	......	......	......	......
			25	1,425	35,505	35,505	73	18,355	8	17,150	......	......	......	......
	Purchased electric power only:	1-200	387	27	10,510	......	......	......	......	......	......	......	......	......
		201-500	19	314	5,968	......	......	......	......	......	......	......	......	......
		501 and above	14	880	12,396	......	......	......	......	......	......	......	......	......
			420	69	28,874	......	......	......	......	......	......	......	......	......
	All other power:	1-200	63	45	2,849	1,855	16	1,260	0	0	29	375	5	220
		201-500	10	288	2,882	1,630	16	1,145	0	0	7	485	0	0
		501 and above	26	5,950	155,085	83,123	67	21,880	25	59,243	3	950	5	1,050
			99	1,625	160,816	86,606	99	24,285	25	59,243	39	1,810	10	1,270
		Total power	544	414	225,195	122,113	172	42,640	33	76,393	39	1,810	10	1,270
		Grand total	574	....	225,195	122,113	172	42,640	33	76,393	39	1.810	10	1,270
14d. Ice, manufactured.	No power		8	......	......	......	......	......	......	......	......	......	......	......
	Steam power only:	1-200	113	100	11,286	11,286	116	10,648	12	638	......	......	......	......
		201-500	43	335	14,415	14,415	113	14,265	2	150	......	......	......	......
		501 and above	49	830	40,630	40,630	278	40,135	5	495	......	......	......	......
			205	323	66,331	66,331	507	65,048	19	1,283	......	......	......	......
	Purchased electric power only:	1-200	21	83	1,747	......	......	......	......	......	......	......	......	......
		201-500	12	333	3,990	......	......	......	......	......	......	......	......	......
		501 and above	15	1,011	15,167.	......	......	......	......	......	......	......	......	......
			48	436	20,904	......	......	......	......	......	......	......	......	......
	All other power:	1-200	46	115	5,291	4,609	42	2,385	3	210	28	1,346	5	66
		201-500	18	332	5,985	4,612	36	3,305	0	0	10	1,107	1	100
		501 and above	13	985	12,807	7,014	32	3,654	3	135	14	3,225	0	0
			77	313	24,083	16,235	110	9,344	6	345	52	5,778	6	768
		Total power	330	337	111,318	82,566	617	74,392	25	1,628	52	5,778	6	768
		Grand total	338	....	111,318	82,566	617	74,392	25	1,628	52	5,778	6	767
14e. Shipbuilding.	No power		43	......	......	......	......	......	......	......	......	......	......	......
	Steam power only:	1-200	20	79	1,575	1,575	34	1,575	0	0	......	......	......	......
		201-500	3	364	1,092	1,092	12	1,092	0	0	......	......	......	......
		501 and above	7	4,745	33,216	33,216	42	10,500	11	22,716	......	......	......	......
			30	1,196	35,883	35,883	88	13,167	11	22,716	......	......	......	......
	Purchased electric power only:	1-200	114	3	333	......	......	......	......	......	......	......	......	......
		201-500	8	326	2,608	......	......	......	......	......	......	......	......	......
		501 and above	13	8,150	106,089	......	......	......	......	......	......	......	......	......
			135	809	109,030	......	......	......	......	......	......	......	......	......
	All other power:	1-200	150	35	5,215	3,127	47	1,617	1	10	154	1,453	2	47
		201-500	16	300	4,807	2,203	28	2,030	0	0	8	173	0	0
		501 and above	19	3,910	74,143	16,265	70	12,208	11	3,470	5	587	0	0
			185	347	84,165	21,595	145	15,855	12	3,480	167	2,213	2	47
		Total power	350	655	229,078	57,478	233	29,022	23	26,196	167	2,213	2	47
		Grand total	393	....	229,078	57,478	233	29,022	23	26,196	167	2,213	2	47

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).	Number.	Horsepower.	Number.	Horsepower.	Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.									
16	17	18	19	20	21	22	23	24	25	26	27
....	....	....	....	....	....	....	....	20	254	272	8
....	....	....	....	30	242	30	242	677	2,508	3,118	10
....	....	....	....	254	2,384	254	2,384	5,908	17,941	23,241	592
....	....	....	....	9,007	42,891	9,007	42,891	5,645	45,828	50,898	2,414
....	....	....	....	9,291	45,517	9,291	45.517	12,230	66,277	77,257	3,016
10,510	3,257	10,510	....	3,257	10,510	....	....	5,963	11,061	16,431	469
5,968	1,267	5,968	....	1,267	5,968	....	....	7,041	17,820	24,140	687
12,396	1,329	12,396	....	1,329	12,396	....	....	5,161	22,955	27,605	400
28,874	5,853	28,874	....	5,853	28,874	....	....	18,165	51,386	68,176	1,556
994	125	767	227	233	1,239	108	472	2,938	4,170	6,810	2
1,252	316	1,252	0	389	1,797	73	545	9,743	8,042	16,802	312
71,962	12,073	71,962	0	25,421	163,894	13,348	91,932	53,991	364,960	414,360	5,782
74,208	12,514	73,981	227	26,043	166,930	13,529	92,949	66,672	377,172	437,972	6,096
103,082	18,367	102,855	227	41,187	241,321	22,820	138,466	97,067	495,285	583,405	10.668
103,082	18,367	102,855	227	41,187	241,321	22,820	138,466	97,087	495,539	583,677	10,676
....	....	....	....	....	....	....	....	7,516	13,493	20,261	0
....	....	....	....	49	482	49	482	23,875	120,156	141,648	1,000
....	....	....	....	162	1,331	162	1,331	25,270	107,876	130,619	0
....	....	....	....	369	4,576	369	4,476	81,195	229,719	302,794	0
....	....	....	....	580	6,389	580	6,389	130,340	457,751	575,061	1,000
1,747	93	1,747	....	93	1,747	....	....	3,145	4,367	7,197	0
3,990	93	3,990	....	93	3,990	....	....	106	388	483	0
15,167	302	15,167	....	302	15,167	....	....	188	13,352	13,616	0
20,904	488	20,904	....	488	20,904	....	....	3,439	18,107	21,196	0
682	70	682	0	101	869	31	187	2,755	25,526	28,005	0
1,373	70	1,373	0	124	1,935	54	562	12,293	23,386	34,447	414
5,793	72	3,843	1,950	146	4,777	74	934	14,430	20,579	33,566	0
7,848	212	5,898	1,950	371	7,581	159	1,683	29,478	69,491	96,018	414
28,752	700	26,802	1,950	1,439	34,874	739	8,072	163,257	545,349	692,375	1,414
28,752	700	26,802	1,950	1,439	34,874	739	8,072	170,773	558,842	712,536	1,414
....	....	....	....	....	....	....	....	382	45	388	0
....	....	....	....	7	60	7	60	1,083	6,902	7,877	122
....	....	....	....	110	795	110	795	2,379	5,737	7,879	0
....	....	....	....	1,341	32,009	1,341	32,009	1,252	191,739	192,864	9,906
....	....	....	....	1,458	32,864	1,458	32,864	4,714	204,378	208,620	10,028
333	328	333	....	328	333	....	....	1,404	2,194	3,454	60
2,608	146	2,608	....	146	2,608	....	....	6,177	2,473	8,035	114
106,089	4,674	106,089	....	4,674	106,089	....	....	10,203	118,790	127,970	29,453
109,030	5,148	109,030	....	5,148	109,030	....	....	17,784	123,457	139,459	29,627
2,088	172	2,073	15	172	2,073	0	0	1,225	5,392	6,494	110
2,604	151	2,394	210	155	2,569	4	175	1,897	8,517	10,227	127
57,878	3,379	57,878	0	3,517	62,147	138	4,269	8,220	154,640	162,038	15,555
62,570	3,702	62,345	225	3,844	66,789	142	4,444	11,342	168,549	178,759	15,792
171,600	8,850	171,375	225	10,450	208,683	1,600	37,308	33,840	496,384	526,838	55,447
171,600	8,850	171,375	225	10,450	208,683	1,600	37,308	34,222	496,429	527,226	55,447

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
			Number.	Average size (horse power).	Aggregate horsepower.	Prime movers.								
						Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
14f. All other miscellaneous industries.	No power		1,834	......	......	......	......	......	......	......	......	......	......	......
	Steam power only:													
		1-200	303	71	21,657	21,657	365	21,242	4	415	......	......	......	......
		201-500	65	319	20,775	20,775	141	20,350	6	425	......	......	......	......
		501 and above	29	1,600	46,524	46,524	165	30,255	24	16,269	......	......	......	......
			397	223	88,956	88,956	671	71,847	34	17,109	......	......	......	......
	Purchased electric power only:													
		1-200	4,791	9	42,920	......	......	......	......	......	......	......	......	......
		201-500	31	275	8,535	......	......	......	......	......	......	......	......	......
		501 and above	13	900	11,758	......	......	......	......	......	......	......	......	......
			4,835	13	63,213	......	......	......	......	......	......	......	......	......
	All other power:													
		1-200	607	41	24,525	16,203	186	9,949	7	212	297	3,797	78	2,245
		201-500	77	307	23,607	14,808	119	11,694	1	250	25	1,185	19	1,679
		501 and above	52	1,340	69,729	42,164	207	26,102	10	13,644	30	532	25	1,886
			736	159	117,861	73,175	512	47,745	18	14,106	352	5,514	122	5,810
	Total power		5,968	45	270,030	162,131	1,183	119,592	52	31,215	352	5,514	122	5,810
	Grand total		7,802	......	270,030	162,131	1,183	119,592	52	31,215	352	5,514	122	5,810
15. Laundries.	No power		33	......	......	......	......	......	......	......	......	......	......	......
	Steam power only:													
		1-200	726	39	28,512	28,512	751	28,042	10	470	......	......	......	......
		201-500	7	286	2,000	2,000	15	2,000	0	0	......	......	......	......
		501 and above	2	890	1,780	1,780	6	1,780	0	0	......	......	......	......
			735	44	32,292	32,292	772	31,822	10	470	......	......	......	......
	Purchased electric power only:													
		1-200	542	12	6,653	......	......	......	......	......	......	......	......	......
	All other power:													
		1-200	278	47	12,953	9,314	203	8,475	7	153	41	588	5	98
		201-500	5	299	1,496	1,275	9	1,275	0	0	0	0	0	0
		501 and above	3	564	1,693	1,490	7	990	2	500	0	0	0	0
			286	56	16,142	12,079	219	10,740	9	653	41	588	5	98
	Total power		1,563	35	55,087	44,371	991	42,562	19	1,123	41	588	5	98
	Grand total		1,596	......	55,087	44,371	991	42,562	19	1,123	41	588	5	98
16a. Anthracite mines.	No power		3	......	......	......	......	......	......	......	......	......	......	......
	Steam power only:													
		1-200	52	60	3,114	3,114	123	3,114	0	0	......	......	......	......
		201-500	5	312	1,560	1,560	32	1,560	0	0	......	......	......	......
		501 and above	77	3,130	241,085	241,085	1,298	206,175	19	34,910	......	......	......	......
			134	1,830	245,759	245,759	1,453	210,849	19	34,910	......	......	......	......
	Purchased electric power only:													
		1-200	27	101	2,736	......	......	......	......	......	......	......	......	......
		201-500	12	345	4,163	......	......	......	......	......	......	......	......	......
		501 and above	9	1,580	14,240	......	......	......	......	......	......	......	......	......
			48	440	21,139	......	......	......	......	......	......	......	......	......
	All other power:													
		1-200	33	58	1,916	1,404	52	775	0	0	54	629	0	0
		201-500	7	344	2,405	1,275	32	1,260	0	0	1	15	0	0
		501 and above	162	3,880	628,507	533,785	3,761	517,257	26	15,755	24	773	0	0
			202	3,130	632,828	536,464	3,845	519,292	26	15,755	79	1,417	0	0
	Total power		384	2,340	899,726	782,223	5,298	730,141	45	50,665	79	1,417	0	0
	Grand total		387	......	899,726	782,223	5,298	730,141	45	50,665	79	1,417	0	0

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
....	....	....	....	....	....	....	....	3,559	9,731	12,931	118
....	....	....	....	483	2,453	483	2,453	23,185	79,714	100,514	2,867
....	....	....	....	833	5,915	833	5,915	29,517	69,594	96,194	671
....	....	....	....	2,691	30,449	2,691	30,449	42,280	248,693	286,000	10,242
....	....	....	....	4,007	38,817	4,007	38,817	94,982	398,001	482,708	13,780
42,920	17,475	42,920	....	17,475	42,920	....	....	27,649	36,968	61,768	663
8,535	569	8,535	....	569	8,535	....	....	2,154	25,075	27,015	79
11,758	977	11,758	....	977	11,758	....	....	2,120	30,447	32,357	0
63,213	19,021	63,213	....	19,021	63,213	....	....	31,923	92,490	121,140	742
8,322	940	6,262	2,060	1,137	7,529	197	1,267	119,020	45,504	152,524	1,503
8,799	818	8,799	0	1,486	12,650	668	3,851	19,239	52,572	69,872	1,211
27,565	1,794	27,565	0	3,213	43,271	1,419	15,706	80,906	150,084	222,784	1,919
44,686	3,552	42,626	2,060	5,836	63,450	2,284	20,824	219,165	248,160	445,180	4,633
107,899	22,573	105,839	2,060	28,864	165,480	6,291	59,641	346,070	738,651	1,049,028	19,155
107,899	22,573	105,839	2,060	28,864	165,480	6,291	59,641	349,629	748,382	1,061,959	19,273
....	....	....	....	....	....	....	....	1,771	247	1,837	0
....	....	....	....	927	3,126	927	3,126	93,616	138,193	222,493	3,234
....	....	....	....	131	705	131	705	4,355	5,575	9,505	0
....	....	....	....	228	1,481	228	1,481	7,217	2,812	9,312	0
....	....	....	....	1,286	5,312	1,286	5,312	105,188	146,580	241,310	3,234
6,653	1,369	6,653	....	1,369	6,653	....	....	24,478	26,357	48,357	1,131
3,639	534	2,254	1,385	972	4,268	438	2,014	37,820	46,670	80,670	407
221	102	221	0	261	634	159	413	4,959	10,806	15,266	39
203	22	203	0	243	636	221	433	4,353	3,601	7,521	0
4,063	658	2,678	1,385	1,476	5,538	818	2,860	47,132	61,077	103,457	506
10,716	2,027	9,331	1,385	4,131	17,503	2,104	8,172	176,798	234,014	393,124	4,871
10,716	2,027	9,331	1,385	4,131	17,503	2,104	8,172	178,569	234,261	394,961	4,871
....	....	....	....	....	....	....	....	90	0	80	0
....	....	....	....	2	60	2	60	17,995	2,749	18,900	0
....	....	....	....	0	0	0	0	17,441	0	15,700	0
....	....	....	....	2,595	120,983	2,595	120,983	2,734,426	0	2,460,000	0
....	....	....	....	2,597	121,043	2,597	121,043	2,769,862	2,749	2,494,600	0
2,736	91	2,736	....	91	2,736	....	....	3,195	0	2,980	0
4,163	112	4,163	....	112	4,163	....	....	2,361	20	2,140	0
14,240	325	14,240	....	325	14,240	....	....	20,085	0	18,100	0
21,139	528	21,139	....	528	21,139	....	....	25,641	20	23,220	0
512	30	512	0	30	512	0	0	1,198	1,327	2,390	0
1,130	42	1,130	0	42	1,130	0	0	24,077	0	21,700	0
94,722	1,281	94,722	0	2,449	159,422	1,168	64,700	5,731,766	25,567	5,180,000	0
96,364	1,353	96,364	0	2,521	161,064	1,168	64,700	5,757,041	26,894	5,204,090	0
117,503	1,881	117,503	0	5,646	303,246	3,765	185,743	8,552,544	29,663	7,721,910	0
117,503	1,881	117,503	0	5,646	303,246	3,765	185,743	8,552,634	29,663	7,721,990	0

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower.)	Establishments.		Power-supply equipment.									
						Prime movers.								
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
16b. Mines and quarries except anthracite.	No power		88	....	....	....	....	....	....	....	....	....	....	....
	Steam power only:	1-200	213	71	15,038	15,038	356	14,837	6	201	....	....	....	....
		201-500	35	314	11,005	11,005	131	11,005	0	0	....	....	....	....
		501 and above	14	1,223	17,158	17,158	114	14,168	5	2,990	....	....	....	....
			262	165	43,201	43,201	601	40,010	11	3,191	....	....	....	....
	Purchased electric power only:	1-200	78	72	5,629	....	....	....	....	....	....	....	....	....
		201-500	8	300	2,405	....	....	....	....	....	....	....	....	....
		501 and above	4	806	3,226	....	....	....	....	....	....	....	....	....
			90	125	11,260	....	....	....	....	....	....	....	....	....
	All other power:	1-200	131	71	9,315	5,863	123	4,036	0	0	93	1,352	7	475
		201-500	41	303	12,431	7,693	117	6,220	0	0	20	377	8	1,096
		501 and above	31	1,123	34,824	18,293	315	14,020	1	275	20	3,848	2	150
			203	279	56,570	31,849	555	24,276	1	275	133	5,577	17	1,721
	Total power		555	200	111,031	75,050	1,156	64,286	12	3,466	133	5,577	17	1,721
	Grand total		643	....	111,031	75,050	1,156	64,286	12	3,466	133	5,577	17	1,721
17. Government institutions.	Steam power only:	1-200	1	20	20	20	1	20	0	0	....	....	....	....
		501 and above	8	6,480	51,856	51,856	34	19,660	20	32,196	....	....	....	....
			9	5,760	51,876	51,876	35	19,680	20	32,196	....	....	....	....
	Purchased electric power only:	1-200	13	70	906	....	....	....	....	....	....	....	....	....
		201-500	1	225	225	....	....	....	....	....	....	....	....	....
			14	81	1,131	....	....	....	....	....	....	....	....	....
	All other power:	501 and above	8	6,340	49,722	25,658	24	10,648	16	14,000	4	100	3	910
	Total power		31	3,350	102,729	77,534	59	30,328	36	46,196	4	100	3	910

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
....	....	....	....	....	....	....	....	35	602	633	....
....	....	....	....	8	195	8	195	5,068	60,586	65,140	41
....	....	....	....	21	386	21	386	3,720	33,484	36,830	0
....	....	....	....	62	4,367	62	4,367	27,133	47,752	72,200	12
....	....	....	....	91	4,948	91	4,948	35,921	141,822	174,170	53
5,629	173	5,629	....	173	5,629	....	....	325	1,440	1,730	0
2,405	31	2,405	....	31	2,405	....	....	0	669	669	0
3,226	70	3,226	....	70	3,226	....	....	64	814	870	0
11,260	274	11,260	....	274	11,260	....	....	389	2,923	3,269	0
3,452	136	3,452	0	136	3,452	....	....	2,683	17,258	19,670	41
4,738	140	4,738	0	141	4,753	1	15	1,607	18,310	19,760	50
16,531	239	16,531	0	292	19,300	53	2,769	5,198	55,212	59,880	184
24,721	515	24,721	0	569	27,505	54	2,784	9,488	90,780	99,310	275
35,981	789	35,981	0	934	43,713	145	7,732	45,798	235,525	276,749	328
35,981	789	35,981	0	934	43,713	145	7,732	45,833	236,127	277,382	328
....	....	....	....	0	0	0	0	0	1,211	1,211	781
....	....	....	....	6,732	74,478	6,732	74,478	12,822	200,078	211,618	2,025
....	....	....	....	6,732	74,478	6,732	74,478	12,822	201,289	212,829	2,806
906	460	906	....	460	906	....	....	3,536	956	4,138	0
225	21	225	....	21	225	....	....	340	0	306	0
1,131	481	1,131	....	481	1,131	....	....	3,876	956	4,444	0
24,064	1,338	24,064	0	5,433	55,814	4,095	31,750	7,677	201,404	208,313	726
25,195	1,819	25,195	0	12,646	131,423	10,827	106,228	24,375	403,649	425,586	3,532

TABLE 47.—*Mechanical power-supply equipment,*

[Data from census of

State.	County.	Size of plant (horsepower).	Establishments reporting power.		Power-supply equipment.					
						Prime movers.				
							Steam engines.		Steam turbines.	
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11
New Hampshire	Cheshire	1-200	141	51	7,209	5,573	68	4,028	3	65
		201-500	22	350	7,692	5,645	32	3,505	1	150
		501 and above	6	938	5,628	4,685	19	3,345	0	0
			169	121	20,529	15,903	119	10,878	4	215
	Hillsborough	1-200	317	33	10,558	6,568	89	4,629	2	75
		201-500	29	262	7,640	5,065	36	3,706	3	450
		501 and above	18	4,920	88,682	67,171	60	21,475	14	30,839
			364	291	106,880	78,804	185	29,810	19	31,364
	Merrimack	1-200	163	40	6,515	3,877	60	2,651	0	0
		201-500	18	316	5,685	5,035	18	2,085	0	0
		501 and above	13	1,710	22,398	18,755	48	6,315	0	0
			194	177	34,598	27,667	126	11,051	0	0
	Rockingham	1-200	164	35	5,724	4,153	71	3,476	0	0
		201-500	3	255	765	765	2	475	0	0
		501 and above	5	2,806	14,030	13,530	19	11,900	2	760
			172	119	20,519	18,448	92	15,851	2	760
Vermont	Bennington	1-200	111	41	4,546	3,712	49	2,426	0	0
		201-500	13	286	3,723	2,770	12	1,765	0	0
		501 and above	6	1,104	6,623	4,273	10	1,830	2	1,363
			130	114	14,892	10,755	71	6,021	2	1,363
	Windham	1-200	147	41	6,081	4,941	65	2,846	0	0
		201-500	15	333	4,996	3,110	18	2,170	0	0
		501 and above	5	2,572	12,862	10,930	20	2,030	0	0
			167	143	23,939	18,981	103	7,046	0	0
Massachusetts	Barnstable	1-200	31	14	432	340	8	222	1	48
		501 and above	1	925	925	900	3	900	0	0
			32	43	1,357	1,240	11	1,122	1	48
	Berkshire	1-200	221	29	6,414	3,401	54	1,871	2	100
		201-500	25	304	7,594	5,319	37	3,928	3	440
		501 and above	29	2,230	64,575	52,112	194	24,726	13	14,658
			275	285	78,583	60,832	285	30,525	18	15,198
	Bristol	1-200	815	22	18,326	6,809	115	5,543	4	135
		201-500	44	298	13,171	7,807	62	6,301	8	760
		501 and above	111	2,820	313,483	255,100	270	214,201	40	37,084
			970	354	344,980	269,716	447	226,045	52	37,979
	Dukes	1-200	12	11	126	121	3	43	0	0
			12	11	126	121	3	43	0	0
	Essex	1-200	1,497	26	38,427	10,992	180	9,889	6	240
		201-500	57	310	17,681	12,569	88	11,584	3	175
		501 and above	58	3,400	196,800	162,990	285	47,318	65	97,787
			1,612	156	252,908	186,551	553	68,791	74	98,202
	Franklin	1-200	181	37	6,699	3,523	36	1,655	1	50
		201-500	7	316	2,213	1,575	3	325	0	0
		501 and above	11	1,937	21,305	14,176	19	3,150	2	1,300
			199	150	30,217	19,274	58	5,130	3	1,350
	Hampden	1-200	652	29	18,995	7,483	95	5,758	1	75
		201-500	44	303	13,307	7,896	52	5,781	2	70
		501 and above	60	3,365	201,932	139,576	225	45,231	37	29,760
			756	310	234,235	154,955	372	56,770	40	29,905
	Hampshire	1-200	145	35	5,135	2,926	34	1,562	2	22
		201-500	12	312	3,745	2,755	14	1,935	0	0
		501 and above	12	2,865	34,380	16,958	20	4,037	5	5,947
			169	255	43,260	22,639	68	7,534	7	5,969

by counties and size of plant.

manufactures, 1919.]

Power-supply equipment—Continued.								Electric motors.				Number of establishments reporting no power.
Prime movers—Continued.				Operated by purchased energy.				Total.		Run by current generated in establishment.		
Internal-combustion engines.		Water wheels.		Total horsepower.	Electric motors.		Other (horsepower).					
Number.	Horsepower.	Number.	Horsepower.		Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.	
12	13	14	15	16	17	18	19	20	21	22	23	24
9	133	33	1,347	1,636	236	1,636	0	237	1,639	1	3	....
0	0	26	1,990	2,047	92	1,932	115	158	2,573	66	641	....
0	0	10	1,340	943	69	943	0	84	1,113	15	170	....
9	133	69	4,677	4,626	397	4,511	115	479	5,325	82	814	17
24	198	44	1,666	3,990	783	3,740	250	799	3,910	16	170	....
0	0	9	909	2,575	273	2,575	0	502	4,249	229	1,674	....
0	0	65	14,857	21,511	1,779	21,511	0	2,879	53,110	1,100	31,599	....
24	198	118	17,432	28,076	2,835	27,826	250	4,180	61,269	1,345	33,443	50
8	126	34	1,100	2,638	453	2,612	26	467	2,696	14	84	....
0	0	34	2,950	650	32	650	0	56	1,006	24	356	....
0	0	46	12,440	3,643	470	3,643	0	562	4,337	92	694	....
8	126	114	16,490	6,931	955	6,905	26	1,085	8,039	130	1,134	20
14	207	14	470	1,571	230	1,571	0	276	1,733	46	162	....
2	230	2	60	0	0	0	0	15	0	15	79	....
0	0	6	870	500	111	500	0	663	6,855	552	6,355	....
16	437	22	1,400	2,071	341	2,071	0	954	8,667	613	6,596	24
14	102	38	1,184	834	132	834	0	132	834	0	0	....
4	50	15	955	953	64	953	0	76	1,271	12	318	....
0	0	11	1,080	2,350	26	2,350	0	168	3,000	142	650	....
18	152	64	3,219	4,137	222	4,137	0	376	5,105	154	968	14
21	167	55	1,928	1,140	242	1,140	0	244	2,780	2	1,640	....
0	0	14	940	1,886	205	1,886	0	325	2,195	120	309	....
0	0	34	8,900	1,932	72	1,932	0	104	2,927	32	995	....
21	167	103	11,768	4,958	519	4,958	0	673	7,902	154	2,944	7
12	59	3	11	92	10	92	0	10	92	0	0	....
0	0	0	0	25	1	25	0	153	2,215	152	2,190	....
12	59	3	11	117	11	117	0	163	2,307	152	2,190	20
18	347	25	1,083	3,013	512	3,001	12	559	3,144	47	143	....
2	110	11	841	2,275	234	2,275	0	316	3,018	82	743	....
0	0	81	12,728	12,463	847	12,463	0	5,334	49,068	4,487	36,605	....
20	457	117	14,652	17,751	1,593	17,739	12	6,209	55,230	4,616	37,491	40
41	484	18	647	11,517	2,023	11,517	0	2,044	11,832	21	315	....
5	221	9	525	5,364	378	5,364	0	487	7,021	109	1,657	....
3	675	46	3,140	58,383	3,849	58,383	0	6,757	106,388	2,908	48,005	....
49	1,380	73	4,312	75,264	6,250	75,264	0	9,288	125,241	3,038	49,977	120
9	78	0	0	5	5	5	0	7	12	2	7	....
9	78	0	0	5	5	5	0	7	12	2	7	6
38	403	13	460	27,435	4,412	21,724	5,711	4,688	23,386	276	1,662	....
0	0	16	810	5,112	584	5,112	0	881	8,962	297	3,850	....
11	870	57	17,015	33,810	4,523	33,810	0	17,011	151,113	12,488	117,303	....
49	1,273	86	18,285	66,357	9,519	60,646	5,711	22,580	183,461	13,061	122,815	210
17	216	45	1,602	3,176	629	3,176	0	757	3,804	128	628	....
1	125	7	1,125	638	61	638	0	116	1,086	55	448	....
0	0	31	9,726	7,129	991	7,129	0	1,128	10,319	137	3,190	....
18	341	83	12,453	10,943	1,681	10,943	0	2,001	15,209	320	4,266	15
14	209	38	1,441	11,512	2,347	11,188	324	2,450	12,090	103	902	....
1	3	27	2,042	5,411	630	5,411	0	1,046	7,685	416	2,274	....
4	52	177	64,533	62,357	2,849	50,257	12,100	5,413	99,418	2,564	49,161	....
19	264	242	68,016	79,280	5,826	66,856	12,424	8,909	119,193	3,083	52,337	135
6	127	36	1,215	2,209	334	2,209	0	399	2,310	65	101	....
0	0	8	820	990	119	990	0	383	1,222	264	232	....
3	635	36	6,339	17,422	1,652	17,422	0	1,850	23,534	198	6,112	....
9	762	80	8,374	20,621	2,105	20,621	0	2,632	27,066	527	6,445	34

TABLE 47.—*Mechanical power-supply equipment,*

State.	County.	Size of plant (horsepower).	Establishments reporting power.		Power-supply equipment.					
					Aggregate horsepower.	Prime movers.				
						Total horsepower.	Steam engines.		Steam turbines.	
			Number.	Average size (horsepower).			Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11
Massachusetts (Continued.)	Middlesex	1-200	1,410	30	43,080	20,548	306	17,702	10	367
		201-500	102	304	31,020	18,936	121	16,741	6	631
		501 and above	81	2,450	198,210	143,116	352	66,246	80	47,138
			1,593	170	272,310	182,600	779	100,689	96	48,136
	Nantucket	1-200	6	27	163	163	3	163	0	0
			6	27	163	163	3	163	0	0
	Norfolk	1-200	420	33	13,902	6,215	98	5,470	1	46
		201-500	38	343	13,063	8,595	44	6,718	3	227
		501 and above	23	1,750	40,473	19,330	40	12,285	10	5,983
			481	140	67,438	34,140	182	24,473	14	6,256
	Plymouth	1-200	370	38	14,067	6,539	81	5,336	1	20
		201-500	34	321	10,906	6,120	43	4,839	3	614
		501 and above	12	1,825	21,998	17,122	29	12,375	12	4,137
			416	112	46,971	29,781	153	22,550	16	4,771
	Suffolk	1-200	2,501	18	44,293	13,368	214	11,971	5	9
		201-500	87	328	28,592	13,039	136	12,112	3	688
		501 and above	46	1,290	59,779	41,082	169	29,777	24	10,380
			2,634	50	132,664	67,489	519	53,860	32	11,077
	Worcester	1-200	1,139	39	43,997	20,451	236	15,414	3	75
		201-500	110	309	34,017	18,653	99	13,358	1	100
		501 and above	101	1,930	195,688	120,340	469	85,413	168	17,011
			1,350	202	273,702	159,444	804	114,185	172	17,186
Rhode Island	Bristol	1-200	53	17	915	259	9	251	0	0
		201-500	1	363	363	0	0	0	0	0
		501 and above	7	2,200	15,401	10,039	13	9,739	1	300
			61	272	16,679	10,298	22	9,990	1	300
	Kent	1-200	76	30	2,305	1,167	18	1,087	0	0
		201-500	5	339	1,695	1,195	6	875	0	0
		501 and above	17	1,705	29,149	29,149	77	17,659	3	2,605
			98	338	33,149	31,511	101	19,621	3	2,605
	Newport	1-200	117	16	1,859	1,344	20	647	2	140
		201-500	1	350	350	0	0	0	0	0
		501 and above	4	2,384	9,537	9,204	8	3,425	3	5,764
			122	96	11,746	10,548	28	4,072	5	5,904
	Providence	1-200	1,549	25	38,610	11,831	207	10,111	4	91
		201-500	86	310	26,550	16,349	127	13,886	3	350
		501 and above	108	2,550	276,181	226,339	320	111,202	58	97,536
			1,743	195	341,341	254,519	654	135,199	65	97,977
	Washington	1-200	87	42	3,659	2,765	30	1,658	1	50
		201-500	14	296	4,156	3,325	20	2,170	0	0
		501 and above	6	957	5,740	4,508	71	3,300	2	900
			107	126	13,555	10,598	121	7,128	3	950
Connecticut	Fairfield	1-200	843	30	25,750	11,585	168	8,356	11	251
		201-500	41	328	13,559	7,233	40	5,233	6	583
		501 and above	48	2,140	102,591	64,848	146	34,457	39	28,300
			932	151	141,900	83,666	354	48,046	56	29,134
	Hartford	1-200	756	27	20,005	6,283	104	5,152	1	50
		201-500	68	304	20,711	12,967	77	9,172	17	524
		501 and above	57	1,640	93,719	43,435	126	26,813	13	5,991
			881	152	134,435	62,685	307	41,137	21	6,565
	Litchfield	1-200	226	30	6,760	4,730	54	2,491	1	12
		201-500	13	313	4,061	3,572	17	2,465	1	167
		501 and above	12	1,840	22,135	18,610	19	6,530	8	11,200
			251	131	32,956	26,912	90	11,386	10	11,379

by counties and size of plant—Continued.

Power-supply equipment—Continued.								Electric motors.				Number of establishments reporting no power.
Prime movers—Continued.				Operated by purchased energy.				Total.		Run by current generated in establishment.		
Internal-combustion engines.		Water wheels.		Total horsepower.	Electric motors.		Other (horsepower).					
Number.	Horsepower.	Number.	Horsepower.		Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.	
12	13	14	15	16	17	18	19	20	21	22	23	24
80	1,413	34	1,067	22,532	4,335	20,621	1,911	4,597	22,336	262	1,715	....
5	379	16	1,185	12,084	1,357	12,084	0	1,973	16,339	616	4,255	....
1	10	113	29,722	55,094	3,809	55,094	0	9,511	124,198	5,702	69,104	....
86	1,802	163	31,974	89,710	9,501	87,799	1,911	16,081	162,873	6,580	75,074	273
0	0	0	0	0	0	0	0	0	0	0	0	....
0.	0	0	0	0	0	0	0	0	0	0	0	3
18	231	13	468	7,687	1,393	7,433	254	1,477	7,779	84	346	....
4	453	17	1,197	4,468	363	4,468	0	671	6,018	308	1,550	....
2	52	17	1,010	21,143	2,106	21,143	0	2,557	28,309	451	7,166	....
24	736	47	2,675	33,298	3,862	33,044	254	4,705	42,106	843	9,062	58
19	351	29	832	7,528	1,368	6,798	730	1,444	7,427	76	629	....
3	136	11	531	4,786	847	4,786	0	910	5,450	63	664	....
0	0	8	610	4,876	506	4,876	0	680	8,360	174	3,484	....
22	487	48	1,973	17,190	2,721	16,460	730	3,034	21,237	313	4,777	53
64	1,224	7	164	30,925	8,866	29,106	1,819	9,392	31,271	526	2,165	....
6	204	1	35	15,553	2,246	15,093	460	3,259	19,044	1,013	3,951	....
5	425	17	500	18,697	1,563	18,497	200	4,809	43,659	3,246	25,162	....
75	1,853	25	699	65,175	12,675	62,696	2,479	17,460	93,974	4,785	31,278	698
44	842	103	4,120	23,546	4,384	23,091	455	4,694	25,223	310	2,132	....
0	0	65	5,195	15,364	1,823	15,364	0	2,513	19,038	690	3,674	....
2	827	76	17,079	75,348	4,151	75,348	0	6,695	106,601	2,544	31,253	....
46	1,669	244	26,404	114,258	10,358	113,803	455	13,902	150,862	3,544	37,059	168
2	8	0	0	656	127	654	2	127	654	0	0	....
0	0	0	0	363	6	363	0	6	363	0	0	....
0	0	0	0	5,362	256	5,362	0	283	6,229	27	867	....
2	8	0	0	6,381	389	6,379	2	416	7,246	27	867	15
6	55	1	25	1,138	329	1,103	35	331	1,126	2	23	....
2	20	3	300	500	43	500	0	188	946	145	446	....
0	0	53	8,885	0	0	0	0	382	4,534	382	4,534	....
8	75	57	9,210	1,638	372	1,603	35	901	6,606	529	5,003	9
32	447	3	110	515	157	515	0	160	523	3	8	....
0	0	0	0	350	45	350	0	45	350	0	0	....
2	15	0	0	333	5	333	0	683	4,876	678	4,543	....
34	462	3	110	1,198	207	1,198	0	888	5,749	681	4,551	25
43	652	27	977	26,779	5,315	25,458	1,321	5,606	27,666	291	2,208	....
1	4	23	2,109	10,201	1,211	10,201	0	1,583	13,404	372	3,203	....
6	3,125	103	14,476	49,842	4,517	49,842	0	10,670	101,936	6,153	52,094	....
50	3,781	153	17,562	86,822	11,043	85,501	1,321	17,859	143,006	6,816	57,505	375
16	104	21	953	894	214	839	55	347	1,079	133	240	....
2	35	23	1,120	831	64	831	0	143	1,523	79	692	....
0	0	6	308	1,232	27	1,232	0	109	2,601	82	1,369	....
18	139	50	2,381	2,957	305	2,902	55	599	5,203	294	2,301	15
65	1,051	33	1,927	14,165	2,400	14,165	0	2,619	15,177	219	1,012	....
4	355	7	1,062	6,326	616	6,326	0	876	9,013	260	2,687	....
8	869	13	1,222	37,743	2,865	37,743	0	6,569	75,237	3,704	37,494	....
77	2,275	33	4,211	58,234	5,881	58,234	0	10,064	99,427	4,183	41,193	160
29	265	27	816	13,722	2,318	13,722	0	2,563	15,298	245	1,576	....
12	238	43	3,033	7,744	583	7,744	0	800	9,773	217	2,029	....
1	60	68	10,571	50,284	2,642	50,284	0	3,966	68,590	1,324	18,306	....
42	563	138	14,420	71,750	5,543	71,750	0	7,329	93,661	1,786	21,911	181
36	545	46	1,682	2,030	288	2,018	12	472	2,941	184	923	....
0	0	16	1,040	489	36	489	0	115	1,555	79	1,066	....
0	0	10	880	3,525	274	3,525	0	603	13,478	329	9,953	....
36	545	72	3,602	6,044	598	6,032	12	1,190	17,974	592	11,942	35

TABLE 47.—*Mechanical power-supply equipment,*

State.	County.	Size of plant (horsepower).	Establishments reporting power.		Power-supply equipment.					
					Aggregate horsepower.	Prime movers.				
						Total horsepower.	Steam engines.		Steam turbines.	
			Number.	Average size (horsepower).			Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11
Connecticut (Continued.)	Middlesex	1-200	205	32	6,476	4,092	55	2,181	2	70
		201-500	13	292	3,796	3,060	15	1,432	1	25
		501 and above	8	765	6,117	3,877	20	2,698	1	30
			226	73	16,389	11,019	90	6,311	4	125
	New Haven	1-200	1,164	23	26,456	9,925	187	8,009	6	215
		201-500	89	325	28,894	18,148	123	15,795	7	809
		501 and above	64	2,520	161,470	106,182	212	48,628	51	49,962
			1,317	164	216,820	134,255	552	72,432	64	50,986
	New London	1-200	257	31	8,129	5,119	64	2,898	2	195
		201-500	29	330	9,622	5,904	55	4,432	0	0
		501 and above	33	1,510	50,002	41,052	72	20,909	9	5,453
			319	212	67,753	52,075	191	28,239	11	5,648
	Tolland	1-200	98	25	2,441	2,098	38	1,266	1	25
		201-500	14	337	4,740	3,724	19	2,210	0	0
		501 and above	7	982	6,871	6,150	23	4,075	0	0
			119	118	14,052	11,972	80	7,551	1	25
	Windham	1-200	178	31	5,313	4,480	62	2,775	3	28
		201-500	8	287	2,298	2,038	7	955	0	0
		501 and above	20	2,469	49,392	45,570	67	23,145	13	7,286
			201	283	57,003	52,088	136	26,875	16	7,314
New York	Albany	1-200	413	29	11,805	3,790	76	3,248	0	0
		201-500	31	310	9,629	4,128	42	4,128	0	0
		501 and above	15	2,670	40,020	11,985	25	7,390	5	4,300
			459	134	61,454	19,903	143	14,766	5	4,300
	Bronx	1-200	880	15	13,121	5,314	50	3,700	2	150
		201-500	12	296	3,554	2,300	20	2,170	0	0
		501 and above	16	1,160	18,484	15,286	106	12,204	5	395
			908	40	35,159	22,900	176	18,074	7	545
	Broome	1-200	238	29	6,852	3,376	53	2,794	2	49
		201-500	13	353	4,604	3,456	23	2,759	6	585
		501 and above	9	1,626	14,633	13,750	25	4,235	6	9,500
			260	100	26,089	20,582	101	9,788	14	10,134
	Columbia	1-200	122	29	3,589	2,707	24	1,342	0	0
		201-500	9	373	3,363	2,933	16	1,773	2	400
		501 and above	10	1,851	18,514	17,320	29	13,315	0	0
			141	180	25,466	22,960	69	16,430	2	400
	Delaware	1-200	163	31	5,141	4,432	115	3,648	0	0
		201-500	1	415	415	415	7	400	0	0
			164	34	5,556	4,847	122	4,048	0	0
	Dutchess	1-200	219	28	6,124	3,136	57	2,067	3	275
		201-500	14	276	3,876	2,204	26	1,640	3	119
		501 and above	13	1,450	18,957	10,016	76	4,728	8	2,545
			246	118	28,957	15,356	159	8,435	14	2,939
	Fulton	1-200	310	27	8,424	4,919	64	4,082	1	125
		201-500	15	316	4,743	2,723	21	2,413	0	0
		501 and above	1	573	573	210	1	150	0	0
			326	42	13,740	7,852	86	6,645	1	125
	Greene	1-200	104	19	1,949	1,216	28	923	1	25
		201-500	3	242	725	625	8	625	0	0
		501 and above	2	8,125	16,250	16,250	4	4,000	3	6,250
			109	173	18,924	18,091	40	5,548	4	6,275
	Herkimer	1-200	155	34	5,255	3,877	46	2,691	0	0
		201-500	20	330	6,607	4,038	25	3,335	0	0
		501 and above	15	1,240	18,606	8,420	31	4,700	0	0
			190	160	30,468	16,335	102	10,726	0	0

by counties and size of plant—Continued.

Power-supply equipment—Continued.								Electric motors.				Number of establishments reporting no power.
Prime movers—Continued.				Operated by purchased energy.				Total.		Run by current generated in establishment.		
Internal-combustion engines.		Water wheels.		Total horse-power.	Electric motors.		Other (horse-power).					
Number.	Horse-power.	Number.	Horse-power.		Number.	Horse-power.		Number.	Horse-power.	Number.	Horse-power.	
12	13	14	15	16	17	18	19	20	21	22	23	24
48	678	34	1,163	2,384	391	2,384	0	434	2,681	43	297	....
7	70	17	1,523	746	60	746	0	117	1,342	57	596	....
5	226	16	923	2,240	373	2,240	0	784	3,506	411	1,266	....
60	974	67	3,609	5,370	824	5,370	0	1,335	7,529	511	2,159	32
74	823	32	878	16,531	3,627	16,319	212	3,756	17,153	129	834	....
6	299	20	1,245	10,746	1,208	10,746	0	1,924	17,516	716	6,770	....
12	2,720	35	4,872	55,288	3,011	55,288	0	7,348	102,805	4,337	47,517	....
92	3,842	87	6,995	82,565	7,846	82,353	212	13,028	137,474	5,182	55,121	356
18	163	13	1,863	3,010	445	3,000	10	577	3,843	132	843	....
5	135	15	1,337	3,718	481	3,718	0	570	4,262	89	544	....
6	1,645	61	13,045	8,950	859	8,950	0	1,646	20,843	787	11,893	....
29	1,943	89	16,245	15,678	1,785	15,668	10	2,793	28,948	1,008	13,280	66
20	196	4	611	343	66	343	0	70	369	4	26	....
0	0	20	1,514	1,016	142	1,016	0	206	1,918	64	902	....
0	0	21	2,075	721	68	721	0	594	4,471	526	3,750	....
20	196	45	4,200	2,080	276	2,080	0	870	6,758	594	4,678	13
31	410	32	1,267	833	216	828	5	222	874	6	46	....
3	276	9	807	260	242	160	0	289	876	47	616	....
0	0	72	15,139	3,822	384	3,822	0	805	8,907	421	5,085	....
34	686	113	17,213	4,915	842	4,910	5	1,316	10,657	474	5,747	22
22	164	7	378	8,015	1,333	8,014	1	1,429	8,620	96	606	....
0	0	0	0	5,501	476	5,501	0	635	6,835	159	1,334	....
0	0	2	295	28,035	915	28,035	0	1,490	40,788	575	12,753	....
22	164	9	673	41,551	2,724	41,550	1	3,554	56,243	830	14,693	138
105	1,464	0	0	7,807	2,550	7,717	90	2,675	10,836	125	3,119	....
1	35	2	95	1,254	155	1,254	0	261	2,067	106	813	....
26	2,687	0	0	3,198	544	3,198	0	978	9,323	434	6,125	....
132	4,186	2	95	12,259	3,249	12,169	90	3,914	22,226	665	10,057	471
27	289	10	244	3,476	749	3,476	0	788	3,729	39	253	....
2	7	3	105	1,148	53	1,148	0	270	2,161	217	1,013	....
1	15	0	0	883	38	883	0	2,638	18,332	2,600	17,449	....
30	311	13	349	5,507	840	5,507	0	3,696	24,222	2,856	18,715	68
17	109	40	1,256	882	155	882	0	163	995	8	113	....
1	5	9	755	430	13	430	0	39	932	26	502	....
1	50	15	3,955	1,194	85	1,194	0	194	4,364	109	3,170	....
19	164	64	5,966	2,506	253	2,506	0	396	6,291	143	3,785	40
41	311	28	473	709	166	709	0	240	1,140	74	431	....
2	15	0	0	0	0	0	0	0	0	0	0	....
43	326	28	473	709	166	709	0	240	1,140	74	431	34
33	385	14	409	2,988	663	2,936	52	689	3,229	26	293	....
0	0	2	445	1,672	184	1,672	0	278	2,647	94	975	....
16	195	9	2,548	8,941	336	8,941	0	1,087	14,392	751	5,451	....
49	580	25	3,402	13,601	1,183	13,549	52	2,054	20,268	871	6,719	61
5	40	25	672	3,505	740	3,440	65	741	3,450	1	10	....
0	0	3	310	2,020	129	2,020	0	196	2,702	67	682	....
0	0	2	60	363	16	363	0	29	556	13	193	....
5	40	30	1,042	5,888	885	5,823	65	966	6,708	81	885	57
15	60	11	208	733	104	733	0	104	733	0	0	....
0	0	0	0	100	2	100	0	7	400	5	300	....
8	6,000	0	0	0	0	0	0	177	8,944	177	8,944	....
23	6,060	11	208	833	106	833	0	288	10,077	182	9,244	27
8	73	32	1,113	1,378	252	1,378	0	284	1,718	32	340	....
7	98	4	605	2,569	195	2,569	0	359	3,801	164	1,232	....
4	15	21	3,705	10,186	578	10,186	0	860	14,176	282	3,990	....
19	186	57	5,429	14,133	1,025	14,133	0	1,503	19,695	478	5,562	33

TABLE 47.—*Mechanical power-supply equipment,*

State.	County.	Size of plant (horsepower).	Establishments reporting power. Number.	Establishments reporting power. Average size (horsepower).	Power-supply equipment. Aggregate horsepower.	Prime movers. Total horsepower.	Steam engines. Number.	Steam engines. Horsepower.	Steam turbines. Number.	Steam turbines. Horsepower.
1	2	3	4	5	6	7	8	9	10	11
New York (Continued.)	Kings	1-200	5,003	17	85,449	26,480	331	21,467	9	264
		201-500	93	314	29,138	14,901	106	14,251	2	130
		501 and above	80	2,129	170,333	105,141	591	80,755	65	23,455
			5,176	55	284,920	146,522	1,028	116,473	76	23,849
	Montgomery	1-200	167	28	4,712	1,786	30	1,193	2	100
		201-500	7	544	2,406	1,275	6	1,275	0	0
		501 and above	13	1,470	19,229	7,722	23	4,357	2	2,700
			187	140	26,347	10,783	59	6,825	4	2,800
	Nassau	1-200	242	14	3,411	1,742	29	1,410	0	0
		201-500	2	263	525	300	1	300	0	0
		501 and above	5	744	3,720	2,960	7	1,685	7	1,175
			249	31	7,656	5,002	37	3,395	7	1,175
	New York	1-200	17,562	8	140,758	29,126	280	23,310	4	245
		201-500	99	328	32,518	15,721	119	15,504	1	50
		501 and above	79	1,215	95,817	66,288	403	63,035	15	2,398
			17,740	15	269,093	111,135	802	101,849	20	2,693
	Oneida	1-200	479	31	14,804	7,783	164	5,064	9	181
		201-500	26	323	8,456	4,881	36	3,838	1	566
		501 and above	29	165	47,947	32,244	61	19,719	23	11,063
			534	134	71,207	44,908	261	28,621	33	11,810
	Orange	1-200	269	27	7,163	4,072	70	3,334	2	123
		201-500	20	287	5,733	4,564	30	3,679	0	0
		501 and above	16	1,055	16,887	10,837	43	7,480	4	2,060
			305	98	29,783	19,473	143	14,493	6	2,183
	Otsego	1-200	120	33	3,956	3,070	65	1,951	0	0
		201-500	1	500	500	500	0	0	0	0
		501 and above	1	1,750	1,750	1,750	7	1,750	0	0
			122	51	6,206	5,320	72	3,701	0	0
	Putnam	1-200	20	24	484	435	11	361	0	0
			20	24	484	435	11	361	0	0
	Queens	1-200	846	26	21,646	7,393	111	5,254	2	144
		201-500	42	288	12,149	6,665	46	6,165	1	400
		501 and above	35	1,700	59,482	49,560	314	31,738	33	17,822
			923	101	93,277	63,618	471	43,157	36	18,366
	Rensselaer	1-200	241	32	7,789	4,877	70	3,616	3	105
		201-500	16	303	4,854	3,234	37	2,780	1	10
		501 and above	18	1,200	21,715	15,850	51	10,104	9	4,170
			275	125	34,358	23,961	158	16,500	13	4,285
	Richmond	1-200	160	16	2,531	1,446	32	1,241	0	0
		201-500	10	334	3,343	1,979	20	1,579	4	400
		501 and above	18	1,775	32,097	20,775	89	19,246	7	979
			188	201	37,971	24,200	141	22,066	11	1,379
	Rockland	1-200	119	30	3,532	2,702	34	2,410	0	0
		201-500	7	400	2,799	2,565	11	2,115	2	450
		501 and above	8	2,327	18,618	16,967	129	12,599	8	4,368
			134	187	24,949	22,234	174	17,124	10	4,818
	Saratoga	1-200	116	35	4,048	2,357	25	1,284	2	65
		201-500	11	287	3,167	2,300	12	990	0	0
		501 and above	17	4,950	84,805	84,167	76	14,495	7	13,650
			144	638	92,020	88,824	113	16,769	9	13,715
	Schenectady	1-200	113	19	2,133	433	7	302	1	5
		201-500	3	318	953	163	5	75	3	88
		501 and above	2	55,800	111,600	56,100	15	11,100	7	45,000
			118	965	114,686	56,696	27	11,477	11	45,093

by counties and size of plant—Continued.

Power-supply equipment—Continued.								Electric motors.				Number of establishments reporting no power.
Prime movers—Continued.				Operated by purchased energy.				Total.		Run by current generated in establishment.		
Internal-combustion engines.		Water wheels.		Total horsepower.	Electric motors.		Other (horsepower).					
Number.	Horsepower.	Number.	Horsepower.		Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.	
12	13	14	15	16	17	18	19	20	21	22	23	24
329	4,744	1	5	58,969	15,079	57,392	1,577	15,567	60,749	488	3,357	....
4	520	0	0	14,237	1,684	14,229	8	2,216	19,896	532	5,667	....
11	931	0	0	65,192	3,769	64,942	250	8,257	115,224	4,488	50,282	....
344	6,195	1	5	138,398	20,532	136,563	1,835	26,040	195,869	5,508	59,306	1,589
6	78	8	415	2,926	567	2,926	0	569	2,941	2	15	....
0	0	0	0	1,131	30	1,131	0	36	1,199	6	68	....
0	0	5	665	11,507	989	11,507	0	1,383	14,923	394	3,416	....
6	78	13	1,080	15,564	1,586	15,564	0	1,988	19,063	402	3,499	34
42	332	0	0	1,669	455	1,669	0	455	1,669	0	0	....
0	0	0	0	225	21	225	0	21	225	0	0	....
1	100	0	0	760	155	760	0	480	1,560	325	800	....
43	432	0	0	2,654	631	2,654	0	956	3,454	325	800	71
408	5,561	10	10	111,632	66,404	108,026	3,606	67,005	113,855	601	5,829	....
8	167	0	0	16,797	2,822	16,432	365	3,236	19,676	414	3,244	....
5	855	0	0	29,529	2,974	27,579	1,950	6,913	53,499	3,939	25,920	....
421	6,583	10	10	157,958	72,200	152,037	5,921	77,154	187,030	4,954	34,993	5,279
50	674	56	1,864	7,021	1,132	7,021	0	1,234	7,753	102	732	....
0	0	5	477	3,575	409	3,575	0	568	5,060	159	1,485	....
3	72	14	1,390	15,703	816	15,703	0	1,672	27,699	856	11,996	....
53	746	75	3,731	26,299	2,357	26,299	0	3,474	40,512	1,117	14,213	170
23	226	9	389	3,091	603	3,091	0	708	4,222	105	1,131	....
5	265	7	620	1,169	436	1,169	0	497	1,996	61	827	....
0	0	10	1,297	6,050	245	6,050	0	691	10,287	446	4,237	....
28	491	26	2,306	10,310	1,284	10,310	0	1,896	16,505	612	6,195	62
22	381	23	738	886	154	886	0	269	1,277	115	391	....
0	0	4	500	0	0	0	0	39	500	39	500	....
0	0	0	0	0	0	0	0	37	595	37	595	....
22	381	27	1,238	886	154	886	0	345	2,372	191	1,486	25
11	74	0	0	49	15	49	0	19	88	4	39	....
11	74	0	0	49	15	49	0	19	88	4	39	4
114	1,995	0	0	14,253	2,962	14,040	213	3,063	14,972	101	932	....
0	0	1	100	5,484	493	5,484	0	877	8,262	384	2,778	....
0	0	0	0	9,922	726	9,922	0	2,781	27,128	2,055	17,206	....
114	1,995	1	100	29,659	4,181	29,446	213	6,721	50,362	2,540	20,916	326
30	376	20	780	2,912	471	2,799	113	706	3,539	235	740	....
0	0	8	444	1,620	121	1,620	0	304	3,099	183	1,479	....
3	10	9	1,566	5,865	289	5,865	0	1,034	11,152	745	5,287	....
33	386	37	2,790	10,397	881	10,284	113	2,044	17,790	1,168	7,506	82
19	202	1	3	1,085	273	985	100	306	1,229	83	244	....
0	0	0	0	1,364	52	1,364	0	115	2,032	63	668	....
3	550	0	0	11,322	390	11,322	0	1,021	18,989	631	7,667	....
22	752	1	3	13,771	715	13,671	100	1,442	22,250	727	8,579	68
5	60	6	232	830	220	730	100	242	970	22	240	....
0	0	0	0	234	9	234	0	42	444	33	210	....
0	0	0	0	1,651	97	1,651	0	257	7,531	160	5,880	....
5	60	6	232	2,715	326	2,615	100	541	8,945	215	6,330	21
13	168	26	840	1,691	231	1,691	0	231	1,691	0	0	....
0	0	15	1,310	867	56	867	0	90	1,167	34	300	....
0	0	70	56,022	638	26	638	0	1,519	14,926	1,493	14,288	....
13	168	111	58,172	3,196	313	3,196	0	1,840	17,784	1,527	14,588	29
5	86	1	40	1,700	341	1,700	0	341	1,700	0	0	....
0	0	0	0	790	250	790	0	250	790	0	0	....
0	0	0	0	55,500	7,680	55,500	0	15,530	114,500	7,850	59,000	....
5	86	1	40	57,990	8,271	57,990	0	16,121	116,990	7,850	59,000	41

TABLE 47.—*Mechanical power-supply equipment,*

State.	County.	Size of plant (horsepower).	Establishments reporting power.		Power-supply equipment.					
					Aggregate horsepower.	Prime movers.				
			Number.	Average size (horsepower).		Total horsepower.	Steam engines.		Steam turbines.	
							Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11
New York (Continued.)	Schoharie	1-200	50	23	1,171	863	24	580	1	10
		201-500	1	361	361	0	0	0	0	0
		501 and above	3	1,611	4,833	3,633	8	1,633	1	2,000
			54	117	6,365	4,496	32	2,213	2	2,010
	Suffolk	1-200	134	19	2,542	1,903	34	1,462	0	0
		201-500	5	351	1,755	1,755	15	1,755	0	0
		501 and above	1	150	1,500	1,500	14	1,500	0	0
			140	41	5,797	5,158	63	4,717	0	0
	Sullivan	1-200	129	23	2,988	2,754	73	2,107	0	0
		201-500	1	480	480	480	4	365	0	0
			130	27	3,468	3,234	77	2,472	0	0
	Ulster	1-200	225	33	7,492	5,064	86	3,627	6	343
		201-500	9	277	2,496	2,056	18	2,051	0	0
		501 and above	10	1,140	11,402	7,288	16	4,670	1	50
			244	87	21,390	14,408	120	10,348	7	393
	Warren	1-200	93	40	3,754	2,133	18	1,036	0	0
		201-500	5	331	1,655	1,025	4	1,025	0	0
		501 and above	6	4,408	26,449	22,022	17	2,668	0	0
			104	305	31,858	25,180	39	4,729	0	0
	Washington	1-200	82	42	3,397	2,107	29	1,091	0	0
		201-509	10	285	2,854	1,609	10	1,065	0	0
		501 and above	15	3,222	48,326	43,568	61	10,101	1	750
			107	510	54,577	47,284	100	12,257	1	750
	West Chester	1-200	596	15	9,103	3,856	71	3,393	2	60
		201-500	23	240	7,811	3,510	32	3,350	1	100
		501 and above	20	2,233	44,656	34,875	160	25,096	32	9,742
			639	97	61,570	42,241	263	31,839	35	9,902
New Jersey	Atlantic	1-200	220	18	3,867	2,403	44	2,052	2	21
		201-500	2	415	830	830	9	830	0	0
		501 and above	1	1,000	1,000	1,000	0	0	1	1,000
			223	26	5,697	4,233	53	2,882	3	1,021
	Bergen	1-200	380	23	8,655	5,305	109	4,373	1	100
		201-500	17	353	6,023	3,235	33	3,183	2	50
		501 and above	29	1,820	52,636	49,244	197	30,461	26	17,104
			426	158	67,314	57,784	339	38,017	29	17,254
	Burlington	1-200	158	31	4,857	4,168	81	3,286	4	205
		201-500	4	384	1,537	1,262	11	1,192	2	70
		501 and above	11	2,470	27,216	23,215	56	21,535	5	690
			173	194	33,610	28,645	148	26,013	11	965
	Camden	1-200	313	33	10,211	6,479	79	4,945	10	575
		201-500	21	290	6,090	4,430	43	4,075	0	0
		501 and above	26	2,290	59,638	51,420	147	17,922	27	32,580
			360	210	75,939	62,329	269	26,942	37	33,155
	Cape May	1-200	78	22	1,720	1,353	35	914	4	135
		201-500	1	250	250	250	1	250	0	0
			79	25	1,970	1,603	36	1,164	4	135
	Cumberland	1-200	210	26	5,532	3,433	67	2,934	2	46
		201-500	6	292	1,752	613	2	135	6	478
		501 and above	3	1,857	5,512	5,510	22	2,760	2	2,350
			219	58	12,796	9,556	91	5,829	10	2,874
	Essex	1-200	2,075	26	52,862	23,913	294	19,779	2	150
		201-500	108	337	36,567	24,791	190	22,662	3	508
		501 and above	57	1,540	87,613	55,560	276	49,213	19	4,884
			2,240	79	177,042	104,264	760	91,654	25	5,542

by counties and size of plant—Continued.

Power-supply equipment—Continued.								Electric motors.				Number of establishments reporting no power.
Prime movers—Continued.				Operated by purchased energy.				Total.		Run by current generated in establishment.		
Internal-combustion engines.		Water wheels.		Total horsepower.	Electric motors.		Other (horsepower).					
Number.	Horsepower.	Number.	Horsepower.		Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.	
12	13	14	15	16	17	18	19	20	21	22	23	24
7	92	12	181	308	47	308	0	48	312	1	4	....
0	0	0	0	361	60	361	0	60	361	0	0	....
0	0	0	0	1,200	12	1,200	0	67	4,137	55	2,937	....
7	92	12	181	1,869	119	1,869	0	175	4,810	56	2,941	16
44	391	2	50	639	174	639	0	188	775	14	136	....
0	0	0	0	0	0	0	0	64	620	64	620	....
0	0	0	0	0	0	0	0	0	0	0	0	....
44	391	2	50	639	174	639	0	252	1,395	78	756	79
28	325	16	322	234	46	234	0	47	239	1	5	....
0	0	2	115	0	0	0	0	0	0	0	0	....
28	325	18	437	234	46	234	0	47	239	1	5	22
14	86	25	1,008	2,428	353	2,413	15	401	2,806	48	393	....
1	5	0	0	440	19	440	0	81	797	62	357	....
6	130	15	2,438	4,114	61	4,114	0	289	7,755	228	3,641	....
21	221	40	3,446	6,982	433	6,967	15	771	11,358	338	4,391	54
11	156	24	941	1,621	224	1,621	0	224	1,621	0	0	....
0	0	0	0	630	6	630	0	27	1,062	21	432	....
1	4	18	19,350	4,427	86	4,427	0	176	5,995	90	1,568	....
12	160	42	20,291	6,678	316	6,678	0	427	8,678	111	2,000	21
6	59	21	957	1,290	280	1,290	0	309	1,470	29	180	....
1	225	4	319	1,245	26	1,245	0	66	1,574	40	329	....
1	20	77	32,697	4,758	225	4,758	0	593	11,430	368	6,672	....
8	304	102	33,973	7,293	531	7,293	0	968	14,474	437	7,181	12
32	349	3	54	5,247	1,596	5,193	54	1,652	5,632	56	439	....
1	60	0	0	4,301	358	4,301	0	1,227	5,915	869	1,614	....
7	37	0	0	9,781	805	9,781	0	2,263	24,753	1,458	14,972	....
40	446	3	54	19,329	2,759	19,275	54	5,142	36,300	2,383	17,025	207
28	330	0	0	1,464	466	1,459	5	544	1,791	78	332	....
0	0	0	0	0	0	0	0	7	54	7	54	....
0	0	0	0	0	0	0	0	221	1,157	221	1,157	....
28	330	0	0	1,464	466	1,459	5	772	3,002	306	1,543	44
63	709	4	123	3,350	989	3,350	0	1,254	4,260	265	910	....
1	2	0	0	2,788	200	2,788	0	313	4,316	113	1,528	....
7	1,679	0	0	3,392	188	3,392	0	3,477	38,983	3,289	35,591	....
71	2,390	4	123	9,530	1,377	9,530	0	5,044	47,559	3,667	38,029	84
51	487	7	190	689	174	689	0	244	981	70	292	....
0	0	0	0	275	8	275	0	14	443	6	168	....
2	740	1	250	4,001	178	4,001	0	929	14,693	751	10,692	....
53	1,227	8	440	4,965	360	4,965	0	1,187	16,117	827	11,152	31
66	894	10	65	3,732	845	3,683	49	964	4,198	119	515	....
4	255	1	100	1,660	139	1,660	0	299	3,425	160	1,765	....
8	889	1	29	8,218	711	7,869	349	3,509	56,183	2,798	48,314	....
78	2,038	12	194	13,610	1,695	13,212	398	4,772	63,806	3,077	50,594	80
26	304	0	0	367	86	367	0	94	436	8	69	....
0	0	0	0	0	0	0	0	2	15	2	15	....
26	304	0	0	367	86	367	0	96	451	10	84	13
39	305	8	148	2,099	486	2,029	70	549	2,337	63	308	....
0	0	0	0	1,139	84	1,139	0	253	2,190	169	1,051	....
0	0	2	400	2	0	0	2	210	3,959	310	3,959	....
39	305	10	548	3,240	570	3,168	72	1,112	8,486	542	5,318	38
210	3,801	3	183	28,949	5,550	27,407	1,542	6,235	31,317	685	3,910	....
47	1,505	2	116	11,776	1,665	11,776	0	2,666	20,102	1,001	8,326	....
14	1,413	1	50	32,053	3,678	32,053	0	7,362	65,013	3,684	32,960	....
271	6,719	6	349	72,778	10,893	71,236	1,542	16,263	116,432	5,370	45,196	447

TABLE 47.—*Mechanical power-supply equipment,*

State.	County.	Size of plant (horsepower).	Establishments reporting power. Number.	Establishments reporting power. Average size (horsepower).	Power-supply equipment. Aggregate horsepower.	Prime movers. Total horsepower.	Steam engines. Number.	Steam engines. Horsepower.	Steam turbines. Number.	Steam turbines. Horsepower.
1	2	3	4	5	6	7	8	9	10	11
New Jersey (Continued.)	Gloucester	1-200	98	22	2,166	1,582	29	1,048	1	4
		201-500	5	360	1,800	1,569	14	945	6	624
		501 and above	4	1,449	5,795	5,195	9	1,660	14	2,297
			107	91	9,761	8,346	52	3,653	21	2,925
	Hudson	1-200	1,731	19	33,285	15,774	254	12,713	5	355
		201-500	81	334	27,135	16,446	134	14,762	7	1,100
		501 and above	79	2,200	173,345	119,763	576	78,894	62	34,118
			1,891	123	233,765	151,983	964	106,369	74	35,573
	Hunterdon	1-200	128	33	4,285	3,968	46	1,861	3	107
		201-500	6	309	1,855	1,855	13	1,600	0	0
		501 and above	6	1,765	10,593	8,095	23	3,836	3	2,300
			140	120	16,733	13,918	82	7,297	6	2,407
	Mercer	1-200	348	30	10,513	6,144	95	5,228	0	0
		201-500	28	350	9,836	7,946	64	6,788	3	733
		501 and above	27	2,120	57,277	45,712	132	30,483	17	13,043
			403	191	77,626	59,802	291	42,499	20	13,776
	Middlesex	1-200	359	26	9,450	4,932	80	4,015	3	155
		201-500	30	344	10,332	6,733	104	6,230	1	225
		501 and above	45	2,600	117,730	101,761	231	69,893	46	29,686
			434	316	137,512	113,426	415	80,138	50	30,066
	Monmouth	1-200	330	16	5,430	2,727	51	1,960	1	15
		201-500	8	339	2,712	1,856	30	1,655	3	186
		501 and above	4	871	3,484	1,868	15	523	4	1,345
			342	34	11,626	6,451	96	4,138	8	1,546
	Morris	1-200	173	24	4,078	2,885	44	2,160	1	12
		201-500	12	1,436	17,226	16,443	59	15,952	4	121
		501 and above	15	1,080	16,198	11,175	40	9,039	5	1,836
			200	188	37,502	30,503	143	27,151	10	1,969
	Ocean	1-200	72	13	965	806	13	349	3	47
		201-500	2	352	705	705	12	600	1	105
			74	23	1,670	1,511	25	949	4	152
	Passaic	1-200	1,137	23	26,544	11,443	179	9,626	20	560
		201-500	65	633	41,200	38,128	611	29,929	19	7,923
		501 and above	26	1,620	42,379	24,902	125	19,851	15	3,890
			1,328	83	110,123	74,473	915	59,406	54	12,373
	Salem	1-200	86	28	2,418	1,768	45	1,209	2	32
		201-500	2	380	761	320	4	320	0	0
		501 and above	2	6,168	12,336	12,336	37	2,361	18	9,975
			90	172	15,515	14,424	86	3,890	20	10,007
	Somerset	1-200	88	70	616	1,573	22	971	0	0
		201-500	7	350	2,452	1,209	10	1,209	0	0
		501 and above	7	1,564	10,945	10,940	14	3,840	5	7,100
			102	157	16,013	13,722	46	6,020	5	7,100
	Sussex	1-200	79	31	2,489	2,312	43	1,576	2	183
		201-500	1	250	250	250	1	150	0	0
		501 and above	3	944	2,833	2,833	15	2,250	1	450
			83	67	5,572	5,395	59	3,976	3	633
	Union	1-200	365	23	8,376	4,061	89	3,018	1	2
		201-500	32	312	10,034	5,962	54	5,380	1	250
		501 and above	21	2,560	53,881	45,898	196	19,489	51	21,751
			418	173	72,291	55,921	339	27,887	53	22,003
	Warren	1-200	145	34	4,853	3,246	49	1,758	2	95
		201-500	9	308	2,773	1,870	12	1,225	0	0
		501 and above	14	1,860	26,013	25,405	86	19,395	10	5,625
			168	200	33,639	30,521	147	22,373	12	5,720

by counties and size of plant—Continued.

Power-supply equipment—Continued.								Electric motors.				Number of establishments reporting no power.
Prime movers—Continued.				Operated by purchased energy.				Total.		Run by current generated in establishment.		
Internal-combustion engines.		Water wheels.		Total horsepower.	Electric motors.		Other (horsepower).					
Number.	Horsepower.	Number.	Horsepower.		Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.	
12	13	14	15	16	17	18	19	20	21	22	23	24
32	354	7	176	584	104	584	0	150	780	46	196	....
0	0	0	0	231	9	231	0	363	1,707	354	1,476	....
5	1,208	2	30	600	2	600	0	342	5,322	340	4,722	....
37	1,562	9	206	1,415	115	1,415	0	855	7,809	740	6,394	26
156	2,571	2	135	17,511	5,466	17,252	259	5,847	20,062	381	2,810	....
11	584	0	0	10,689	1,072	10,689	0	2,285	18,021	1,213	7,332	....
30	6,751	0	0	53,582	4,430	53,582	0	9,736	114,171	5,306	60,589	....
197	9,906	2.	135	81,782	10,968	81,523	259	17,868	152,254	6,900	70,731	493
45	638	43	1,362	317	92	317	0	100	392	8	75	....
0	0	4	255	0	0	0	0	20	140	20	140	....
4	12	6	1,947	2,498	110	2,498	0	419	6,282	309	3,784	....
49	650	53	3,564	2,815	202	2,815	0	539	6,814	337	3,999	12
30	450	21	466	4,369	989	4,367	2	1,155	5,262	166	895	....
2	50	5	375	1,890	160	1,620	270	545	4,093	385	2,473	....
6	2,111	1	75	11,565	810	11,565	0	1,968	29,067	1,158	17,502	....
38	2,611	27	916	17,824	1,959	17,552	272	3,668	38,422	1,709	20,870	108
37	572	6	190	4,518	888	4,368	150	996	5,321	108	953	....
6	278	0	0	3,599	297	3,349	250	523	5,294	226	1,945	....
18	2,160	2	22	15,969	1,131	15,969	0	4,291	67,247	3,160	51,278	....
61	3,010	8	222	24,086	2,316	23,686	400	5,810	77,862	3,494	54,176	72
46	485	8	267	2,703	708	2,670	33	714	2,708	6	38	....
4	15	0	0	856	77	856	0	77	856	0	0	....
0	0	0	0	1,616	62	1,616	0	72	1,741	10	125	....
50	500	8	267	5,175	847	5,142	33	863	5,305	16	163	54
17	264	16	449	1,193	281	1,193	0	385	1,458	104	265	....
0	0	4	370	783	42	783	0	410	4,206	368	3,423	....
2	15	5	285	5,023	79	5,023	0	523	12,574	444	7,551	....
19	279	25	1,104	6,999	402	6,999	0	1,318	18,238	916	11,239	33
33	299	4	111	159	68	159	0	68	159	0	0	....
0	0	0	0	0	0	0	0	2	6	2	6	....
33	299	4	111	159	68	159	0	70	165	2	6	19
82	1,041	12	216	15,101	3,161	12,409	2,692	3,454	14,840	293	2,431	....
5	161	2	115	3,072	378	2,597	475	1,223	6,902	845	4,305	....
4	811	4	350	17,477	1,253	17,477	0	3,849	48,467	2,596	30,990	....
91	2,013	18	681	35,650	4,792	32,483	3,167	8,526	70,209	3,734	37,726	209
23	168	13	359	650	103	650	0	108	724	5	74	....
0	0	0	0	441	29	441	0	96	831	67	390	....
0	0	0	0	0	0	0	0	434	7,681	434	7,681	....
23	168	13	359	1,091	132	1,091	0	638	9,236	506	8,145	19
20	307	9	295	1,043	329	1,043	0	416	1,253	87	210	....
0	0	0	0	1,243	79	1,243	0	109	1,536	30	293	....
0	0	0	0	5	1	5	0	476	6,943	475	6,938	....
20	307	9	295	2,291	409	2,291	0	1,001	9,732	592	7,441	20
27	306	7	247	177	157	177	0	195	542	38	365	....
7	100	0	0	0	0	0	0	6	60	6	60	....
1	8	2	125	0	0	0	0	38	292	38	292	....
35	414	9	372	177	157	177	0	239	894	82	717	11
55	1,021	1	20	4,315	974	4,315	0	1,073	4,961	99	646	....
23	332	0	0	4,072	505	4,072	0	714	5,846	209	1,774	....
18	4,658	0	0	7,983	547	7,983	0	2,677	39,787	2,130	31,804	....
96	6,011	1	20	16,370	2,026	16,370	0	4,464	50,594	2,438	34,224	69
37	1,398	0	0	1,607	322	1,607	0	531	2,264	209	657	....
7	645	0	0	903	43	903	0	132	2,131	89	1,228	....
2	385	0	0	608	13	608	0	946	16,116	933	15,508	....
46	2,428	0	0	3,118	378	3,118	0	1,609	20,511	1,231	17,393	13

TABLE 47.—*Mechanical power-supply equipment,*

State.	County.	Size of plant (horsepower).	Establishments reporting power.		Power-supply equipment.					
					Aggregate horsepower.	Prime movers.				
			Number.	Average size (horsepower).		Total horsepower.	Steam engines.		Steam turbines.	
							Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11
Pennsylvania	Berks	1-200	780	29	22,881	11,835	252	9,488	7	168
		201-500	30	312	9,357	4,719	48	4,583	2	136
		501 and above	40	1,549	61,954	47,897	205	45,442	10	1,790
			850	110	94,192	64,451	505	59,513	19	2,094
	Bucks	1-200	359	24	8,486	6,436	124	4,575	4	292
		201-500	5	278	1,390	1,387	14	1,312	1	75
		501 and above	8	1,888	15,107	14,857	26	8,684	5	5,743
			372	67	24,983	22,680	164	14,571	10	6,110
	Carbon	1-200	94	43	4,034	2,348	35	1,443	1	8
		201-500	5	336	1,682	1,285	9	785	0	0
		501 and above	14	3,630	50,686	38,424	102	21,649	6	16,675
			113	498	56,402	42,057	146	23,877	7	16,683
	Chester	1-200	278	36	10,005	6,490	114	5,067	5	81
		201-500	20	303	6,053	4,460	33	3,790	4	575
		501 and above	15	6,670	101,944	89,258	355	65,816	44	16,082
			313	377	118,002	100,208	502	74,673	53	16,738
	Columbia	1-200	165	30	5,007	3,781	60	2,323	2	30
		201-500	9	265	2,387	1,787	13	1,257	3	305
		501 and above	5	3,545	18,725	11,930	68	11,215	1	500
			179	145	26,119	17,498	141	14,795	6	835
	Dauphin	1-200	356	25	9,060	5,434	157	4,905	2	40
		201-500	28	302	8,464	4,405	39	3,615	3	170
		501 and above	18	7,000	125,845	109,479	310	76,806	5	9,040
			402	355	143,369	119,318	506	85,326	10	9,250
	Delaware	1-200	214	37	7,833	5,869	76	4,935	0	0
		201-500	24	341	8,215	6,961	44	6,090	2	266
		501 and above	35	3,840	134,854	39,934	227	23,876	26	15,343
			273	550	150,902	52,764	347	34,901	28	15,609
	Lackawanna	1-200	384	37	14,294	3,752	72	3,611	3	30
		201-500	42	293	12,291	4,619	64	4,578	0	0
		501 and above	77	2,320	179,597	163,966	914	140,746	14	23,220
			503	410	206,182	172,337	1,050	148,935	17	23,250
	Lancaster	1-200	670	31	20,991	10,845	156	7,260	8	161
		201-500	22	314	6,946	2,137	21	2,137	0	0
		501 and above	15	1,510	22,707	10,347	68	9,978	4	312
			707	72	50,644	23,329	245	19,375	12	473
	Lebanon	1-200	242	34	8,145	4,377	100	3,521	0	0
		201-500	11	290	3,194	1,815	25	1,815	0	0
		501 and above	9	5,655	51,059	49,275	148	36,000	7	9,675
			262	237	62,398	55,467	273	41,336	7	9,675
	Lehigh	1-200	430	36	15,329	9,363	161	7,490	1	20
		201-500	27	300	8,104	4,395	61	3,796	4	220
		501 and above	26	2,750	71,140	50,546	184	50,493	0	0
			483	195	94,573	64,304	406	61,779	5	240
	Luzerne	1-200	465	30	13,752	6,727	143	5,943	1	110
		201-500	36	334	12,026	6,015	56	6,015	0	0
		501 and above	102	3,060	311,995	267,720	1,708	245,042	22	22,568
			603	560	337,773	280,462	1,907	257,000	23	22,678
	Monroe	1-200	78	36	2,792	1,975	34	1,345	1	62
		201-500	4	232	929	390	3	210	0	0
		501 and above	1	1,651	1,651	1,200	3	300	0	0
			83	65	5,372	3,565	40	1,855	1	62
	Montgomery	1-200	573	36	20,446	12,667	215	10,754	4	185
		201-500	31	306	9,515	6,330	44	6,043	0	0
		501 and above	30	3,055	91,658	72,482	188	45,247	41	26,570
			634	192	121,619	91,479	447	62,044	45	26,755

by counties and size of plant—Continued.

Power-supply equipment—Continued.								Electric motors.				Number of establishments reporting no power.
Prime movers—Continued.				Operated by purchased energy.				Total.		Run by current generated in establishment.		
Internal-combustion engines.		Water wheels.		Total horse-power.	Electric motors.		Other (horse-power).					
Number.	Horse-power.	Number.	Horse-power.		Number.	Horse-power.		Number.	Horse-power.	Number.	Horse-power.	
12	13	14	15	16	17	18	19	20	21	22	23	24
73	915	64	1,264	11,046	2,395	11,046	0	2,541	11,766	146	720	....
0	0	0	0	4,638	821	4,638	0	879	5,356	58	718	....
4	540	2	125	14,057	808	14,057	0	2,424	34,543	1,616	20,486	....
77	1,455	66	1,389	29,741	4,024	29,741	0	5,844	51,665	1,820	21,924	216
102	911	23	658	2,050	391	2,023	27	456	2,362	65	339	....
0	0	0	0	3	2	3	0	26	158	24	155	....
2	30	2	400	250	2	250	0	540	11,953	538	11,703	....
104	941	25	1,058	2,303	395	2,276	27	1,022	14,473	627	12,197	136
17	432	9	465	1,686	164	1,656	30	164	1,656	0	0	....
0	0	6	500	397	18	397	0	18	397	0	0	....
0	0	2	100	12,262	334	12,262	0	1,008	34,338	674	22,076	....
17	432	17	1,065	14,345	516	14,315	30	1,190	36,391	674	22,076	19
24	346	49	996	3,515	591	3,430	85	630	3,719	39	289	....
0	0	3	95	1,593	52	1,593	0	113	2,360	61	767	....
8	7,270	3	90	12,686	495	12,686	0	2,119	49,585	1,624	36,899	....
32	7,616	55	1,181	17,794	1,138	17,709	85	2,862	55,664	1,724	37,955	44
37	325	38	1,103	1,226	195	1,226	0	201	1,291	6	65	....
0	0	7	225	600	146	600	0	158	885	12	285	....
5	215	0	0	6,795	342	6,795	0	1,026	13,490	684	6,695	....
42	540	45	1,328	8,621	683	8,621	0	1,385	15,666	702	7,045	18
29	148	14	341	3,626	1,021	3,626	0	1,072	3,954	51	328	....
10	620	0	0	4,059	330	4,059	0	790	5,536	460	1,477	....
24	23,633	0	0	16,366	814	16,366	0	3,707	76,640	2,893	60,274	....
63	24,401	14	341	24,051	2,165	24,051	0	5,569	86,130	3,404	62,079	62
49	668	9	266	1,964	359	1,964	0	402	2,355	43	391	....
6	425	3	180	1,254	132	1,254	0	442	4,916	310	3,662	....
5	590	4	125	94,920	4,539	94,920	0	6,387	119,638	1,848	24,718	....
60	1,683	16	571	98,138	5,030	98,138	0	7,231	126,909	2,201	28,771	46
11	68	2	43	10,542	1,480	10,452	90	1,550	10,648	70	196	....
0	0	3	41	7,672	618	7,672	0	709	8,975	91	1,303	....
0	0	0	0	15,631	557	15,631	0	2,743	100,923	2,186	85,292	....
11	68	5	84	33,845	2,655	33,755	90	5,002	120,546	2,347	86,791	74
73	848	122	2,576	10,146	1,741	10,126	20	1,967	11,298	226	1,172	....
0	0	0	0	4,809	449	4,809	0	469	4,849	20	40	....
2	17	2	40	12,360	1,494	12,360	0	1,595	14,019	101	1,659	....
75	865	124	2,616	27,315	3,684	27,295	20	4,031	30,166	347	2,871	231
39	290	28	566	3,768	619	3,768	0	651	4,138	32	370	....
0	0	0	0	1,379	73	1,379	0	139	3,108	66	1,729	....
3	3,600	0	0	1,784	61	1,784	0	533	18,553	472	16,769	....
42	3,890	28	566	6,931	753	6,931	0	1,323	25,799	570	18,868	66
31	374	46	1,479	5,966	1,540	5,791	175	1,600	6,451	60	660	....
2	214	1	165	3,709	849	3,709	0	934	4,288	85	579	....
7	27	2	26	20,594	901	20,594	0	1,067	22,777	166	2,183	....
40	615	49	1,670	30,269	3,290	30,094	175	3,601	33,516	311	3,422	100
35	311	10	363	7,025	1,469	7,025	0	1,600	7,766	131	741	....
0	0	0	0	6,011	649	6,011	0	1,274	8,502	625	2,491	....
7	110	0	0	44,275	2,949	44,275	0	4,930	124,098	1,981	79,823	....
42	421	10	363	57,311	5,067	57,311	0	7,804	140,366	2,737	83,055	85
22	352	11	216	817	286	817	0	287	837	1	20	....
0	0	3	180	539	39	539	0	39	539	0	0	....
0	0	3	900	451	13	451	0	13	451	0	0	....
22	352	17	1,296	1,807	338	1,807	0	339	1,827	1	20	17
74	789	42	939	7,779	1,269	7,779	0	1,464	9,346	195	1,567	....
2	37	1	250	3,185	258	3,185	0	487	5,944	229	2,759	....
3	665	0	0	19,176	1,257	19,176	0	3,401	60,927	2,144	41,751	....
79	1,491	43	1,189	30,140	2,784	30,140	0	5,352	76,217	2,568	46,077	120

TABLE 47.—*Mechanical power-supply equipment,*

State.	County.	Size of plant (horsepower).	Establishments reporting power.		Power-supply equipment.					
					Aggregate horsepower.	Prime movers.				
						Total horsepower.	Steam engines.		Steam turbines.	
			Number.	Average size (horsepower).			Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11
Pennsylvania (Continued.)	Montour	1-200	37	22	815	495	11	315	1	50
		201-500	2	239	478	327	3	300	2	27
		501 and above	6	1,190	7,133	6,775	43	6,775	0	0
			45	187	8,426	7,597	57	7,390	3	77
	Northampton	1-200	338	42	14,173	7,794	151	6,341	2	24
		201-500	37	305	11,316	6,124	111	5,985	0	0
		501 and above	38	5,550	211,730	170,869	327	103,481	42	18,588
			413	575	237,219	184,787	589	115,807	44	18,612
	Northumberland	1-200	256	33	8,422	4,907	95	4,444	3	100
		201-500	15	317	4,757	3,115	43	3,115	0	0
		501 and above	29	3,370	97,736	92,359	699	85,969	3	6,150
			300	369	110,915	100,381	837	93,528	6	6,250
	Philadelphia	1-200	6,334	19	122,520	67,618	931	54,250	20	754
		201-500	234	320	74,929	58,113	476	55,558	6	710
		501 and above	177	1,930	342,513	231,172	1,137	188,950	73	35,582
			6,745	80	539,962	356,903	2,544	298,758	99	37,046
	Pike	1-200	18	23	409	389	8	219	1	50
		501 and above	1	2,598	2,598	2,598	27	2,008	0	0
			19	158	3,007	2,987	35	2,227	1	50
	Schuylkill	1-200	373	25	9,130	5,344	125	4,581	4	83
		201-500	15	315	4,732	3,080	65	2,980	0	0
		501 and above	69	4,250	293,142	246,779	1,612	241,970	11	4,627
			459	670	307,004	255,203	1,802	249,531	15	4,710
	Susquehanna	1-200	62	28	1,723	1,197	24	951	0	0
		201-500	1	255	255	250	1	250	0	0
		501 and above	1	1,868	1,868	900	2	900	0	0
			64	60	3,846	2,347	27	2,101	0	0
	Wayne	1-200	146	30	4,429	3,699	71	2,348	1	16
		201-500	1	450	450	450	1	450	0	0
		501 and above	3	1,871	5,614	5,144	29	4,444	0	0
			150	70	10,493	9,293	101	7,242	1	16
	Wyoming	1-200	45	32	1,424	1,338	18	775	0	0
		201-500	3	337	1,010	1,010	18	1,010	0	0
		501 and above	1	1,400	1,400	1,400	4	1,400	0	0
			49	78	3,834	3,748	40	3,185	0	0
	York	1-200	563	34	18,995	11,450	205	9,164	0	0
		201-500	32	300	9,584	6,612	41	6,308	2	100
		501 and above	18	1,810	32,675	13,199	65	7,352	5	2,450
			613	100	61,254	31,261	311	22,824	7	2,550
Delaware	Kent	1-200	104	29	3,042	2,895	80	1,995	2	20
		201-500	1	273	273	273	7	220	0	0
		501 and above	0	0	0	0	0	0	0	0
			105	32	3,315	3,168	87	2,215	2	20
	New Castle	1-200	262	42	10,961	7,676	125	6,732	1	2
		201-500	16	316	5,064	4,421	50	3,136	4	500
		501 and above	29	2,040	59,182	44,274	173	29,610	14	12,508
			307	245	75,207	56,371	348	39,478	19	13,010
District of Columbia		1-200	439	22	9,865	4,311	54	3,131	0	0
		201-500	12	294	3,539	2,390	26	2,145	2	145
		501 and above	14	3,550	49,764	35,582	66	13,369	20	20,613
			465	135	63,163	42,283	146	18,645	22	20,758

by counties and size of plant—Continued.

Power-supply equipment—Continued. Prime movers—Continued. Internal-combustion engines. Number.	Power-supply equipment—Continued. Prime movers—Continued. Internal-combustion engines. Horsepower.	Power-supply equipment—Continued. Prime movers—Continued. Water wheels. Number.	Power-supply equipment—Continued. Prime movers—Continued. Water wheels. Horsepower.	Power-supply equipment—Continued. Operated by purchased energy. Total horsepower.	Power-supply equipment—Continued. Operated by purchased energy. Electric motors. Number.	Power-supply equipment—Continued. Operated by purchased energy. Electric motors. Horsepower.	Power-supply equipment—Continued. Operated by purchased energy. Other (horsepower).	Electric motors. Total. Number.	Electric motors. Total. Horsepower.	Electric motors. Run by current generated in establishment. Number.	Electric motors. Run by current generated in establishment. Horsepower.	Number of establishments reporting no power.
12	13	14	15	16	17	18	19	20	21	22	23	24
7	79	4	51	320	67	320	0	67	320	0	0	....
0	0	0	0	151	32	151	0	32	151	0	0	....
0	0	0	0	358	18	358	0	19	363	1	5	....
7	79	4	51	829	117	829	0	118	834	1	5	13
21	195	41	1,234	6,379	1,392	6,379	0	1,443	7,021	51	642	....
2	4	2	135	5,192	325	5,192	0	347	5,437	22	245	....
23	48,500	4	300	40,861	2,134	40,861	0	10,038	232,743	7,904	191,882	....
46	48,699	47	1,669	52,432	3,851	52,432	0	11,828	245,201	7,977	192,769	49
25	270	4	93	3,515	560	3,515	0	677	3,904	117	389	....
0	0	0	0	1,642	36	1,642	0	407	1,860	371	218	....
6	240	0	0	5,377	203	5,377	0	1,283	20,889	1,080	15,512	....
31	510	4	93	10,534	799	10,534	0	2,367	26,653	1,568	16,119	41
807	12,525	9	89	54,902	15,110	48,915	5,987	17,201	59,801	2,091	10,886	....
20	1,685	3	160	16,816	1,925	16,201	615	5,216	38,649	3,291	22,448	....
17	4,640	3	2,000	111,341	9,062	111,341	0	20,213	241,732	11,151	130,391	....
844	18,850	15	2,249	183,059	26,097	176,457	6,602	42,630	340,182	16,533	163,725	2,427
8	45	3	75	20	1	20	0	1	20	0	0	....
5	590	0	0	0	0	0	0	0	0	0	0	....
13	635	3	75	20	1	20	0	1	20	0	0	11
41	398	14	282	3,786	773	3,786	0	811	4,059	38	273	....
4	100	0	0	1,652	110	1,652	0	186	2,366	76	714	....
9	182	0	0	46,363	520	46,363	0	1,008	66,935	488	20,572	....
54	680	14	282	51,801	1,403	51,801	0	2,005	73,360	602	21,559	90
11	161	3	85	526	73	526	0	73	526	0	0	....
0	0	0	0	5	2	5	0	26	218	24	213	....
0	0	0	0	968	46	968	0	46	968	0	0	....
11	161	3	85	1,499	121	1,499	0	145	1,712	24	213	17
13	121	33	1,214	730	130	862	48	148	831	18	149	....
0	0	0	0	0	0	0	0	0	0	0	0	....
0	0	2	700	470	81	470	0	288	2,822	207	2,352	....
13	121	35	1,914	1,200	211	1,152	48	436	3,653	225	2,501	21
17	179	11	384	86	10	46	40	10	46	0	0	....
0	0	0	0	0	0	0	0	2	30	2	30	....
0	0	0	0	0	0	0	0	44	751	44	751	....
17	179	11	384	86	10	46	40	56	827	46	781	5
89	670	83	1,616	7,545	1,336	7,450	95	1,555	8,713	219	1,263	....
6	204	0	0	2,972	309	2,972	0	513	4,264	204	1,292	....
2	7	18	3,390	19,476	1,577	19,476	0	1,600	19,965	23	489	....
97	881	101	5,006	29,993	3,222	29,898	95	3,668	32,942	446	3,044	428
33	504	18	376	147	59	147	0	64	197	5	50	....
4	53	0	0	0	0	0	0	0	0	0	0	....
0	0	0	0	0	5	0	0	5	0	0	0	....
37	557	18	376	147	64	147	0	69	197	5	50	6
18	222	22	720	3,285	699	3,240	45	723	3,456	24	216	....
6	160	6	625	643	73	643	0	177	1,768	104	1,125	....
3	15	3	2,141	14,908	760	14,908	0	2,272	38,522	1,512	23,614	....
27	397	27	3,486	18,836	1,532	18,791	45	3,172	43,746	1,640	24,955	59
55	739	3	441	5,554	2,048	5,544	10	2,174	6,039	126	495	....
0	0	1	100	1,149	121	1,149	0	247	2,412	126	1,263	....
6	1,475	1	125	14,182	1,041	14,182	0	7,070	68,987	6,029	54,805	....
61	2,214	5	666	20,885	3,210	20,875	10	9,491	77,438	6,281	56,563	170

TABLE 47.—*Mechanical power-supply equipment,*

State.	County.	Size of plant (horsepower).	Establishments reporting power.		Power-supply equipment.					
					Aggregate horse-power.	Prime movers.				
						Total horse-power.	Steam engines.		Steam turbines.	
			Num-ber.	Aver-age size (horse-power).			Num-ber.	Horse-power.	Num-ber.	Horse-power.
1	2	3	4	5	6	7	8	9	10	11
Maryland	Anne Arundel	1-200	44	25	1,075	685	28	531	1	10
		201-500	2	299	597	250	1	250	0	0
		501 and above	2	983	1,965	0	0	0	0	0
			48	76	3,637	935	29	781	1	10
	Baltimore	1-200	90	25	2,285	1,646	38	1,146	0	0
		201-500	6	301	1,808	1,492	22	1,492	0	0
		501 and above	7	15,300	107,089	83,870	11	21,470	13	4,495
			103	1,080	111,182	87,008	71	24,108	13	4,495
	Baltimore City	1-200	1,863	38	70,862	18,411	295	16,035	5	315
		201-500	99	317	31,412	18,659	161	17,787	7	271
		501 and above	74	1,730	128,473	41,591	413	35,342	28	4,153
			2,036	113	230,747	78,661	869	69,164	40	4,739
	Cecil	1-200	78	36	2,854	2,455	50	1,638	0	0
		501 and above	6	884	5,308	5,308	76	4,880	0	0
			84	97	8,162	7,763	126	6,518	0	0
	Harford	1-200	164	24	3,961	3,295	132	2,190	1	15
		201-500	5	282	1,410	1,380	13	780	0	0
		501 and above	1	750	750	750	0	0	1	750
			170	36	6,121	5,425	145	2,970	2	765
	Kent	1-200	44	35	1,548	1,541	34	1,149	1	12
			44	35	1,548	1,541	34	1,149	1	12
	Prince Georges	1-200	46	16	746	734	32	620	0	0
			46	16	746	734	32	620	0	0
	Queen Annes	1-200	41	24	1,002	933	32	766	0	0
			41	24	1,002	933	32	766	0	0

by counties and size of plant—Continued.

Power-supply equipment—Continued.								Electric motors.				Number of establishments reporting no power.
Prime movers—Continued.				Operated by purchased energy.				Total.		Run by current generated in establishment.		
Internal-combustion engines.		Water wheels.		Total horse-power.	Electric motors.		Other (horse-power).					
Number.	Horse-power.	Number.	Horse-power.		Number.	Horse-power.		Number.	Horse-power.	Number.	Horse-power.	
12	13	14	15	16	17	18	19	20	21	22	23	24
3	144	0	0	390	80	390	0	81	399	1	9	....
0	0	0	0	347	25	347	0	25	347	0	0	....
0	0	0	0	1,965	51	1,965	0	51	1,965	0	0	....
3	144	0	0	2,702	156	2,702	0	157	2,711	1	9	7
15	96	20	404	639	63	635	4	83	792	20	157	....
0	0	0	0	316	101	316	0	101	316	0	0	....
17	55,700	11	2,205	23,219	698	23,219	0	2,745	133,314	2,047	110,095	....
32	55,796	31	2,609	24,174	862	24,170	4	2,929	134,422	2,067	110,252	28
138	1,887	3	174	52,451	6,011	52,342	109	6,511	54,709	500	2,367	....
16	601	0	0	12,753	1,059	12,753	0	1,824	17,996	765	5,243	....
10	2,096	0	0	86,882	5,555	86,882	0	6,427	97,128	872	10,256	....
164	4,584	3	174	152,086	12,625	151,977	109	14,762	169,843	2,137	17,866	796
23	180	23	637	399	38	399	0	69	491	31	92	....
7	128	2	300	0	0	0	0	15	193	15	193	....
30	308	25	937	399	38	399	0	84	684	46	285	12
41	389	24	701	666	77	666	0	77	666	0	0	....
0	0	2	600	30	2	30	0	2	30	0	0	....
0	0	0	0	0	0	0	0	12	745	12	745	....
41	389	26	1,301	696	79	696	0	91	1,441	12	745	11
24	249	6	131	7	2	7	0	3	9	1	2	....
24	249	6	131	7	2	7	0	3	9	1	2	1
14	114	0	0	12	6	12	0	6	12	0	0	....
14	114	0	0	12	6	12	0	6	12	0	0	23
11	69	6	98	69	10	69	0	10	69	0	0	....
11	69	6	98	69	10	69	0	10	69	0	0	3

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	Power analysis.							Coal analysis.							
			Portion of prime movers (column 7) (except water wheels) that might have been replaced by superpower.		Motor horsepower required to replace prime movers in column 33 and energy to be purchased for them from superpower system.			Coal used for power by prime movers (column 33) and coal used in conjunction with them for heating and process work.							
								Total.		For power.		For heating and process work.			
gy ped ime ers mn n nds iva- ilo- t- s.	Factor B.[b]	Energy purchased for power (column 16) in thousands of kilowatt-hours.	Per cent of column 7 minus column 15.	Horsepower.	Motor horsepower per prime-mover horsepower.	Total horsepower.	Energy required (thousands of kilowatt-hours).	Per cent of column 26.	Short tons.	Per cent of column 38.	Short tons.	Per cent of column 38.	Short tons.	Coal required by superpower system to supply energy in column 36 (short tons).	Coal saved by superpower system (short tons).
	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
000	2,000	34,000	81	27,000	1.1	29,700	59,400	79	330,000	75	248,000	25	82,000	59,400	188,600
000	820	10,300	99	17,000	1.0	17,000	14,000	87	38,000	96	36,500	4	1,500	14,000	22,500
800	700	30,000	92	17,000	1.2	20,200	14,200	30	136,000	25	34,000	75	102,000	14,200	19,800
000															
000	740	59,000	91	88,500	1.0	88,500	65,000	72	594,000	60	356,000	40	238,000	65,000	291,000
000	1,350	245,000	87	500,000	1.0	500.000	675,000	77	1,500,000	80	1,200,000	20	300,000	675,000	525,000
400	900	32,400	37	17,000	1.1	18,700	17,000	24	85,000	50	42,500	50	42,500	17,000	25,500
000	900	53,000	74	54,000	1.1	59,500	54,000	57	240,000	60	144,000	40	96,000	54,000	90,000
000	1,300	80,000	20	54,000	1.0	54,000	70,500	12	162,000	80	130,000	20	32,000	70,500	59,500
800	1,040	6,500	29	7,000	1.0	7,000	7,300	19	47,000	40	18,800	60	28,200	7,300	11,500
000	850	20,000	23	25,000	1.2	30,000	25,500	8	75,000	80	60,000	20	15.000	25,500	34,500
000	1,200	27,500	65	40,000	1.0	40,000	48,000	42	120,000	80	96,000	20	24,000	48,000	48,000
000	650	37,300	60	15,000	1.0	15,000	9,700	28	105,000	60	63,000	40	42,000	9,700	53,300
600	1,300	31,900	54	12,000	1.0	12,000	15,600	39	108,000	75	81,000	25	27,000	15,600	65,400
000	1,000	400													
000	1,000	81,500	38	185,000	1.0	185,000	185,000	40	1,630,000	75	1,220,000	25	410,000	185,000	1,035,000
000	825	40,000	77	17,000	1.3	22,000	18,000	44	107,000	65	70,000	35	37,000	18,000	52,000
000	780	342,000	97	442,000	1.2	531,000	415,600	69	2,050,000	75	1,540,000	25	510,000	415,600	1,124,400
700	720	3,500													
500	480	33,200	88	112,000	1.3	145,000	7,000	80	320,000	75	240,000	25	80,000	70,000	170,000
000	1,500	45,000	17	10,000	1.0	10,000	15,000	20	100,000	25	25,000	75	75,000	15,000	10,000
600	900	39,800	80	35,000	0.9	31,500	28,000	51	140,000	33	46,000	67	94,000	28,000	18,000
000	3,000	168,000	49	110,000	1.0	110,000	330,000	40	900,000	80	720,000	20	18,000	330,000	390,000
500	1,000	24,000	94	28,700	1.2	34,000	34,000	83	156,000	75	117,000	25	39,000	34,000	83,000
000	1,000	136,700	100	31,000	1.2	37,000	37,000	65	133,000	90	120,000	10	13,000	37,000	83,000
000	470	5,700	71	71,000	1.0	71,000	33,000	68	481,000	27	130,000	73	351,000	33,000	97,000
000	600	12,000	75	15,000	1.0	15,000	9,000	38	1,500,000	4	60,000	96	1,440,000	9,000	51,000
000	1,500	5,200	100	15,300	1.0	15,300	23,000	96	277,000	27	75,000	73	202,000	23,000	52,000
000	600	2,600	60	62,000	1.0	62,000	37,000	46	1,600,000	12	200,000	88	1,400,000	37,000	163,000
000	1,300	2,000	23	15,000	1.0	15,000	20,000	23	300,000	23	69,000	77	231,000	20,000	49,000
000	1,500	158,000	65	125,000	1.0	125,000	188,000	55	1,548,000	50	774,000	50	774,000	188,000	586,000
000	4,000	190,000	25	29,000	1.0	29,000	116,000	25	525,000	40	210,000	60	315,000	116,000	94,000
000	580	20,200	97	40,000	1.0	40,000	23,000	68	236,000	50	118,000	50	118,000	23,000	95,000
000	520	13,700	91	59,000	1.0	59,000	30,600	73	640,000	20	128,000	80	512,000	30,600	97,400
000	1,600	11,600	83	4,800	1.1	5,300	8,500	60	145,000	25	36,000	75	109,000	8,500	27,500
000	2,800	280,000	90	175,000	1.2	210,000	590,000	77	1,315,000	60	789,000	40	526,000	590,000	199,000
500	1,120	65,000	95	45,000	1.2	54,000	61,000	72	217,000	80	173,000	20	44,000	61,000	112,000
400	960	6,300	100	8,500	1.0	8,500	8,100	79	52,000	68	35,300	32	16,700	8,100	27,200
400	900	38,000	95	15,000	1.2	18,000	16,200	41	69,000	53	36,500	47	32,500	16,200	20,300
500	1,200	20,600	100	5,400	1.0	5,400	6,500	36	42,000	50	21,000	50	21,000	6,500	14,500
100	760	5,800	100	5,600	1.0	5,600	4,200	42	15,000	50	7,500	50	7,500	4,200	3,300
000	2,000	65,000	100	67,000	1.0	67,000	134,000	79	734,000	50	367,000	50	367,000	134,000	233,000
640	800	15,000	100	800	1.0	800	600	14	6,000	80	4,800	20	1,200	600	4,200
000	910	24,600	94	30,000	1.0	30,000	127,300	65	140,000	45	63,000	55	77,000	27,300	35,700
000	1,250	109,000	83	70,000	1.2	84,000	105,000	63	444,000	50	222,000	50	222,000	105,000	117,000
000	1,250	129,000	76	92,000	1.2	110,000	142,000	51	300,000	50	150,000	50	150,000	142,000	8,000
000	2,400	68,000	96	79,000	1.1	87,000	210,000	96	680,000	99	673,000	1	7,000	210,000	463,000
000	1,200	205,000	100	57,000	1.5	85,000	102,000	59	310,000	78	242,000	22	68,000	102,000	140,000
000	1,060	115,000	87	136,000	1.0	136,000	145,000	74	773,000	65	503,000	35	270,000	145,000	358,000
500	800	8,600	23	10,000	1.0	10,000	8,000	25	100,000	20	20,000	80	80,000	8,000	12,000
000	1,040	123,000	100	782,000	1.5	1,170,000	1,215,000	99	7,657,000	92	7,012,000	8	645,000	1,215,000	5,797,000
500	780	28,000	100	73,000	1.0	73,000	57,000	96	266,000	93	247,000	7	19,000	57,000	190,000
000	1,240	31,000	100,	76,600	1.5	115,000	96,000	87	370,000	41	152,000	59	218,000	96,000	53,000
440	1,200	3,338,800	70	4,008,200	1.18	4,703,000	5,623,800	56	29,818,000	64	19,125,900	36	10,692,100	5,623,800	13,502,100

ANALYSIS OF INDUSTRIES.

GENERAL FEATURES.

In order to determine the quantity of coal that might be saved and the amount of power that might have been economically supplied by purchased energy, the detailed statistics of the industries shown in Table 46 were submitted to several engineers and manufacturers, who analyzed the data and gave their opinions as to the amount of energy that might have been economically purchased and the resulting saving of fuel. In the estimates made by this survey due regard has been given to the opinions thus obtained.

The results of this analysis are shown in Table 48. The headings for columns 5 to 27 in Table 48 are the same as the corresponding headings in Tables 44, 45, and 46. Other columns are explained as follows:

Column 29 is column 7 multiplied by column 28.

Column 31 is column 16 multiplied by column 30.

Column 32 is the ratio, in per cent, of column 33 to the difference between column 7 and column 15.

For each size of power plant in each industry the prime mover that might have been replaced by superpower was determined. The sum of these items is shown in column 33.

Column 34 shows the motor horsepower per prime-mover horsepower as determined by the authorities consulted.

Column 35 is column 33 multiplied by column 34.

Column 36 is column 35 multiplied by factor B (column 30).

Column 37 is ratio in per cent of column 38 to column 26.

Column 43 is based on a consumption by the superpower system of 2 pounds of coal per kilowatt-hour delivered at the motor leads. Column $43 = \frac{\text{column } 36 \times 1000 \times 2}{2000}$.

Column 44 equals column 40 minus column 43.

This table shows that the energy developed by prime movers in the industries in 1919 was equivalent to 9,311,440,000 kilowatt-hours and that the energy purchased was 3,338,800,000 kilowatt-hours, a total of 12,650,240,000 kilowatt-hours; also that it would have been economical to shut down 4,008,200 horsepower of prime movers, exclusive of water wheels, and to purchase additional energy to the amount of 5,623,800,000 kilowatt-hours, which would have made a total of 8,962,600,000 kilowatt-hours of purchased electrical energy.

The total coal used for power by prime movers that might have been replaced by superpower and the coal used in conjunction with them for heating and in manufacturing processes was 29,818,000 tons, of which 19,125,900 tons was used for power and 10,692,100 tons for heating and in manufacturing processes. If the energy developed by these prime movers had been purchased, the 19,125,900 tons of coal burned for power would have been replaced by 5,623,800 tons burned at the central stations (at the rate of 2 pounds of coal per kilowatt-hour as measured at the motor leads), a saving of 13,502,100 tons. That is, 71 per cent of the coal used for power by the prime movers or 25 per cent of the total coal used by the industries might have been saved.

In estimating the fuel saved by the superpower system (Table 48) the percentages given in columns 39 and 41, "For power" and "For heating and process work," are to be construed not as percentages for the whole industry but as percentages for only that part for which purchased energy might have been supplied. These percentages were obtained from the analyses made by the authorities consulted.

Column 33 shows the power that might have been supplied economically to each industry by a superpower system. In determining this item the groups that use waste gases for fuel, that use waste-heat boilers, and that have water power were omitted. In all but a very few industries it was found to be more economical for plants of less than 200 horsepower to purchase all the energy they require, regardless of their requirements for heat. Almost the same is true for plants of 201 to 500 horsepower. It is only in plants that are larger than 500 horsepower and that have some special requirements for heat that the generation of power can be justified. Even in these plants the power supply and demand can not be completely balanced, and central-station connections should be available for taking up irregularities.

SECONDARY SAVINGS.

In this analysis the only fuel saving credited to the purchase of electrical energy is the direct saving in the production of power. Experience has shown that in plants using purchased power much of the fuel formerly used for process heat can be saved through the simplification of the heating arrangements by the elimination of power production. Further, it was assumed in the analysis that much prime-mover power would be retained, owing to the use of waste-heat boilers and strict modernization of power-producing equipment. Such improvements would undoubtedly also result in an improvement in the heating arrangements similar to that found in an establishment purchasing electrical energy.

WATERWORKS.

The accompanying tables do not include the mechanical power-supply equipment or fuel used by waterworks, because these plants are usually considered in a different class from industries. A survey of the waterworks in the superpower zone shows that they used 260,000 long tons of anthracite and 260,000 short tons of bituminous coal in 1919. To replace this coal would require 340,000,000 kilowatt-hours of energy, the generation of which would require 340,000 tons of coal, at 2 pounds of coal per kilowatt-hour at the motor leads; this indicates a saving of the equivalent of 154,000 tons of bituminous coal. The possible load due to waterworks has not been included in any figure of this analysis.

COMMENTS ON SPECIAL INDUSTRIES.

The industry using the largest amount of coal is anthracite mining, and in this industry a coal saving of more than 75 per cent could be made if the mines were supplied from an efficient central electric power system. The present large consumption may be accounted for by the use of inefficient prime movers, long steam lines, inefficient pumps, and improper boiler and furnace design for burning the coal.

Many industries could save coal by the use of waste-heat boilers. Probably the greatest saving by this means could be made in the cement industry. It is estimated that if waste-heat boilers had been in use in all the cement plants in the superpower zone in 1919, 540,000 tons of coal would have been saved.

There are many blast furnaces in the superpower zone which are isolated from any steel plants or rolling mills, and approximately half their gases are wasted. These gases would produce sufficient heat for boilers to generate 500,000,000 kilowatt-hours a year.

In certain plants the low-pressure steam requirements greatly exceed the power requirements, and there is no reason why such plants should not generate by-product power and sell it to the electrical distributing companies.

ENERGY REQUIRED BY LOAD CENTERS.

Table 49 gives the electric energy in kilowatt-hours that might have been supplied by a superpower system in 1919 to replace the energy produced by prime movers in isolated plants. The factors for energy requirements obtained from the analysis summarized in Table 48 were applied to the detailed data for each industry in the Bureau of the Census, and the results summarized by load centers are given in Table 49.

TABLE 49.—*Electric energy, in kilowatt-hours, that might have been supplied by a superpower system in 1919 to replace the energy produced by prime movers in isolated plants.*

Load center.	Total energy at motors.	Portion of energy for anthracite mines at motors.
Boston	206,000,000	
Lowell	193,500,000	
Providence	536,000,000	
Worcester	130,000,000	
Northampton	105,500,000	
Hartford	103,000,000	
New Haven	277,000,000	
Albany	155,000,000	
Utica	59,800,000	
New York	460,000,000	
Newark	625,000,000	
Hudson	40,000,000	
Wilkes-Barre	860,700,000	785,200,000
Allentown	162,000,000	
Pottsville	495,500,000	415,470,000
Baltimore	125,000,000	
Harrisburg	230,800,000	14,780,000
Philadelphia	698,000,000	
Trenton	121,000,000	
Washington	40,000,000	
	5,623,800,000	1,215,450,000

PREDICTION OF FUTURE LOAD.

Figure 17 shows the past and predicted future industrial mechanical power-supply equipment. The past has been plotted from Census data and the future from the past and the opinion of several authorities on industrial development in the zone. It is shown in Table 48 that on the average 1.18 horsepower of motors is required to replace 1 horsepower of prime movers. The increase in recent years of motors operated by purchased energy has therefore affected the aggregate horsepower, giving the curve an increased slope. This has been considered in predicting the 1930 value, which shows an increase in the aggregate horsepower of 33 per cent from 1919. If the ratio of motors operated by purchased energy to aggregate horsepower remained as in 1919 the increase in aggregate horsepower in 1930 would be only 20 per cent.

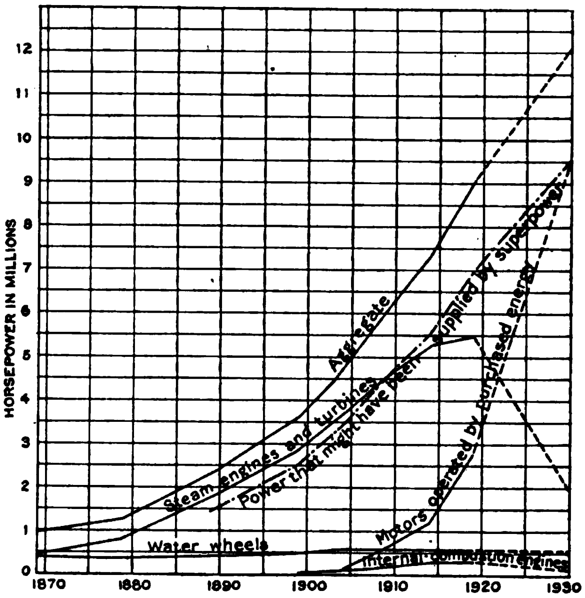

FIGURE 17.—Past and predicted future mechanical power-supply equipment used by industries in superpower zone, 1870–1930.

The curve of horsepower that might have been supplied by superpower as drawn in figure 17 is based on the analysis in Table 48 for 1919. As in that year 4,008,200 horsepower of prime movers would have been replaced by 4,703,000 horsepower of motors, it has been necessary to consider the ratios discussed in the preceding paragraph in plotting this curve. When "saturation" is reached in 1930 these considerations are eliminated; prior to that time the form of the curve is correct, but exact values have been adjusted in consideration of the actual horsepower of motors operated by purchased energy.

COST OF INDUSTRIAL POWER.

Figures 18 and 19 show the comparative cost of power generated in isolated condensing plants of capacities up to 5,000 kilowatts, operating at four load factors, and of purchased power for the same capacities. For the same load factor the curve of the cost of purchased power is considerably below the cost of generated power. As these curves represent condensing plants, all noncondensing plants, where the exhaust steam is not utilized in manufacturing, would realize an even greater saving by the purchase of power.

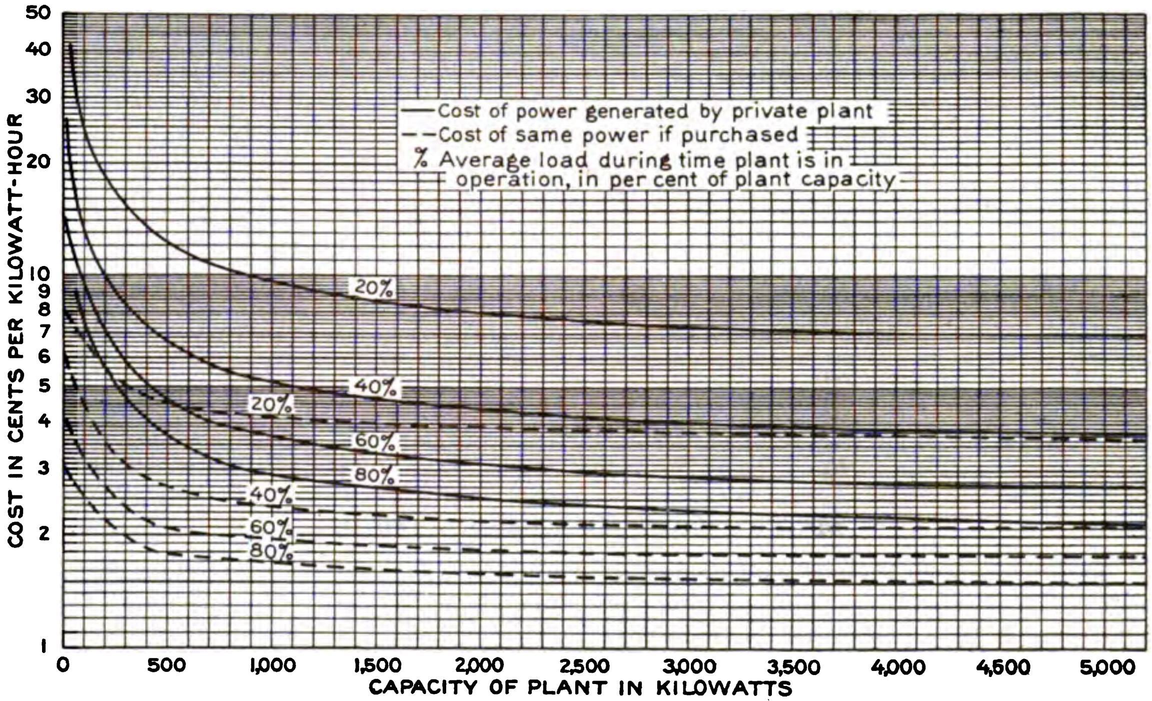

FIGURE 18.—Cost of electric power for industrial plants operating one shift daily. Based on prices and central-station rates prevailing in July, 1919. Coal figured at $5.18 per short ton delivered. Fixed charges, 16 per cent.

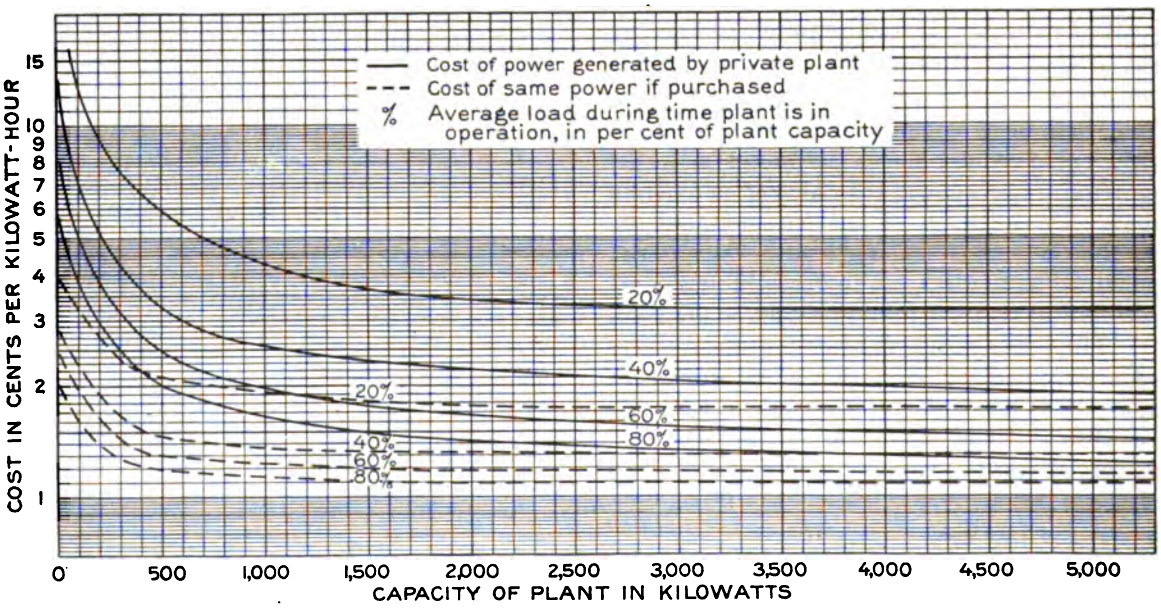

FIGURE 19.—Cost of electric power for industrial plants operating three shifts daily. Based on prices and central-station rates prevailing in July, 1919. Coal figured at $5.18 per short ton delivered. Fixed charges, 16 per cent.

ISOLATED PLANTS.

The cost of power shown for isolated plants includes all labor, fuel, and fixed charges. Labor rates are those of 1919. Fuel was charged at $5.18 per short ton delivered. Fixed charges, including interest, depreciation, taxes, and insurance, were taken as 16 per cent of the investment cost as of 1919. The isolated plants were assumed to be designed in accordance with the best modern practice.

CENTRAL STATIONS.

The central-station rates shown on the curves are the average rates in force in 1919 for several electric utilities that used coal-produced energy exclusively and that supply approximately 400,000,000 kilowatt-hours yearly for industrial power at these rates. The rates are adjusted to coal at $5.18 per short ton delivered. At the present time these rates are typical of the large central stations only and not of the smaller companies, which are prevented by limitations of generating capacity from soliciting large power loads. These limitations would, however, be removed by the development of a complete unified system of electric supply.

SAVING IN COST OF POWER TO INDUSTRIES.

In Table 50 are given estimates showing the saving in cost of power to the industries possible by a change from the several types of power-supply equipment actually used in 1919 to the maximum economical use of purchased electrical energy. The costs of power have been taken from figure 18, the data being applied in detail to each type and average size of plant, and the estimates therefore show the difference between average best isolated-plant practice and central-station service. Savings are also shown for 1930 on the same basis as for 1919. A fixed charge of 16 per cent per annum has been made against electrification, based on the cost of motors at $35 per horsepower installed. It is to be noted that in either 1919 or 1930, when the maximum purchase of electrical energy is considered, the aggregate horsepower is greater, owing to the ratio of motor to engine horsepower, as explained in connection with figure 17. The figures in the last two columns of the table are rounded to represent the nearest $10,000,000.

TABLE 50.—*Possible saving in annual cost of industrial power through maximum economical use of purchased electrical energy, 1919 and 1930.*

1919.

	Horsepower.		
Actual proportion of power-supply equipment, 9,069,000 horsepower (average cost, $55 per horsepower-year)			$500,000,000
With maximum purchase of electrical energy:			
9,764,000 horsepower (average cost, $32 per horsepower-year)		$310,000,000	
Motors required	4,703,000		
Motors now installed and available (21 per cent)	990,000		
New motors required	3,713,000		
Cost of motors installed, $130,000,000.			
Motor fixed charge, at 16 per cent		20,000,000	
			330,000,000
Possible saving			170,000,000

1930.

	Horsepower.		
Arrested development, based on a supply of industrial power by equipment in the same proportion as was actually used in 1919, 11,100,000 horsepower (average cost, $55 per horsepower-year)			$610,000,000
With maximum purchase of electrical energy:			
12,150,000 horsepower (average cost, $32 per horsepower-year)		$390,000,000	
Motors required	6,700,000		
Motors now installed and available (21 per cent)	1,400,000		
New motors required	5,300,000		
Cost of motors installed, $185,000,000.			
Motor fixed charge, at 16 per cent		30,000,000	
			420,000,000
Possible saving			190,000,000

APPENDIX E.

PERFORMANCE AND COST OF THE SUPERPOWER SYSTEM.

By Henry Flood, jr., A. R. Wellwood, and others of the engineering staff.

GENERAL CONDITIONS.

The accompanying tables and diagrams show the investment cost and the cost of power delivered by a superpower system to the load centers in 1919, in 1925, and in 1930. St. Lawrence and Niagara power will probably not be available until after 1930, but the effect of St. Lawrence power on the Eastern New England, Western New England, and Mohawk-Hudson divisions and that of Niagara power on the Metropolitan division are shown for 1932.

The cost of delivering power from a superpower system in 1930 if all the new power plants were of the steam-electric type is mentioned in order to justify the construction of both steam-electric and hydro-electric plants as proposed.

The figures given for cost of superpower operation, including those for 1919, are of course hypothetical; the figures for independent operation in 1919, where given, represent actual cost.

DEMAND AND ENERGY.

Table 51 shows the estimated demand and energy for the superpower system in 1919, 1925, and 1930. These estimates are based on the rate of growth of the utilities, the industries, and the railroads within the zone.

The figures in the first two columns in this table show the peak demand for power and the energy used during the year 1919 that could have been economically supplied by a superpower system. The figures in the second column include, first, the energy actually supplied by electric public-utility companies as reported by them; second, the energy now generated and used by isolated plants of industries that might have obtained it more economically from a superpower system, as determined by a method stated in detail in Appendix D (p. 143); third, the energy required for the heavy-traction load, which includes that of the railroads which can be economically electrified.

The figures showing the demand in 1919 were derived from the load factor of the energy actually supplied to the load centers in that year. The industrial and railroad loads that were added naturally tended to raise the load factor, but in order to be conservative the electric-utility load factor used was that for 1919.

Table 51.—*Demand and energy requirements for superpower zone.*

Geographic division and load center.	1919		1925		1930	
	Demand (thousands of kilowatts).	Energy (millions of kilowatt-hours).	Demand (thousands of kilowatts).	Energy (millions of kilowatt-hours).	Demand (thousands of kilowatts).	Energy (millions of kilowatt-hours).
Eastern New England:						
Boston	296.0	1,069.7	382	1,439	492	1,886
Lowell	107.6	390.5	36	136	45	173
Newburyport			54	203	67	257
Brockton			27	102	41	155
Providence	291.0	1,019.8	161	608	246	939
New Bedford			71	266	108	414
Worcester	148.1	535.9	187	704	244	931
	842.7	3,015.9	918	3,458	1,243	4,755

TABLE 51.—*Demand and energy requirements for superpower zone*—Continued.

Geographic division and load center.	1919		1925		1930	
	Demand (thousands of kilowatts).	Energy (millions of kilowatt-hours).	Demand (thousands of kilowatts).	Energy (millions of kilowatt-hours).	Demand (thousands of kilowatts).	Energy (millions of kilowatt-hours).
Western New England:						
Bridgeport	....	....	115	428	146	555
New Haven	244.0	869.8	64	239	81	308
Norwich	....	....	39	144	49	184
Waterbury	....	....	44	165	57	218
Hartford	75.9	270.6	80	297	103	392
Northampton	148.5	530.4	136	507	173	657
Pittsfield	....	....	35	129	43	163
	468.4	1,670.8	513	1,909	652	2,477
Mohawk-Hudson:						
Schenectady	201.0	811.9	233	973	300	1,263
Utica	58.6	238.5	92	383	162	680
Poughkeepsie	62.1	262.5	56	356	83	374
Port Jervis	....	....	34	155	46	209
	321.7	1,312.9	415	1,767	591	2,526
Metropolitan:						
New York	923.0	3,595.5	1,270	5,066	1,570	6,393
Paterson	....	....	55	219	66	271
Newark	513.0	1,994.5	360	1,438	461	1,878
New Brunswick	....	....	45	180	59	239
	1,436.0	5,590.0	1,730	6,903	2,156	8,781
Anthracite:						
Scranton	....	....	120	569	168	771
Wilkes-Barre	346.2	1,592.9	145	687	218	1,000
Hazleton	....	....	156	737	229	1,051
Allentown	150.0	689.4	58	276	78	359
Pottsville	157.2	723.0	70	331	92	425
	653.4	3,005.3	549	2,600	785	3,606
Southern:						
Trenton	91.3	376.2	83	342	99	426
Philadelphia	534.0	2,202.7	706	2,983	1,040	4,459
Reading	....	....	106	448	144	619
Harrisburg	212.2	875.7	161	681	219	941
Wilmington	....	....	46	196	65	282
Baltimore	223.1	921.7	291	1,229	336	1,447
Washington	71.2	292.9	84	354	92	393
	1,131.8	4,669.2	1,477	6,233	1,995	8,567
Superpower zone	4,854.0	19,264.1	5,602	22,870	7,422	30,712

Figure 20 shows the distribution of load in the superpower zone for 1925 and 1930 and is comparable to figure 1 (p. 33), showing the distribution of the electric-utility load in 1919.

Figure 21 shows the load in 1919 and 1930 for each center compared with that of New York, which has been taken at 100 per cent. This chart shows the decentralization that should occur between those years through the agency of a superpower system. The electrification of heavy-traction railroads and of isolated industrial plants will be effective in relieving the congestion of load at the larger centers. For 1919 only 20 load centers are designated for the electric-utility load; for 1925 and 1930 the number of centers is increased to 34. For these later years the heavy-traction railroad load is added to that of the electric utilities, thus making it desirable and economical to tap the transmission system at a larger number of points. However, from the cost of substations given in Appendix H it is evident that it will not be economical to tap the transmission system for a load of less than 20,000 kilowatts.

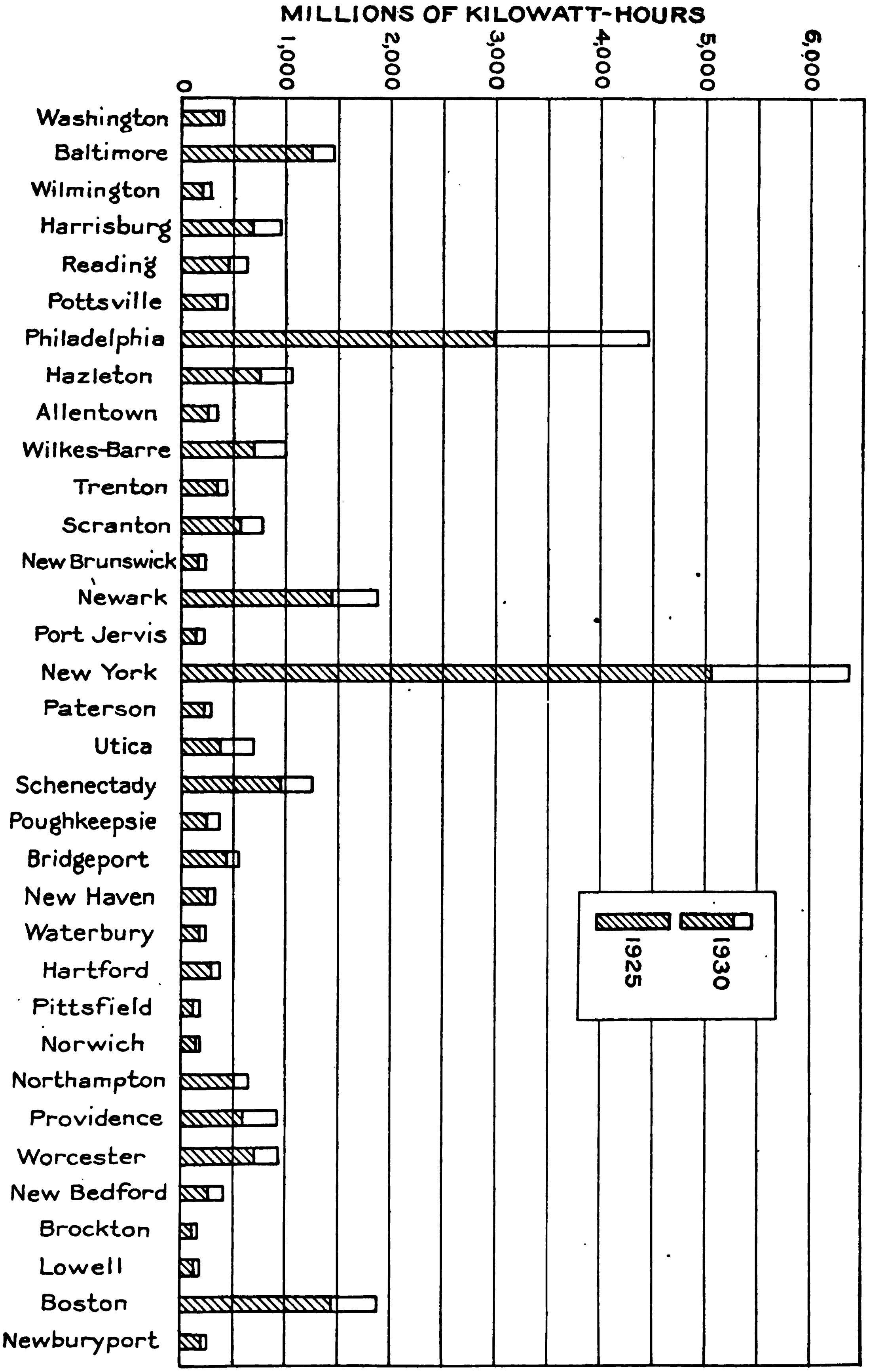

FIGURE 20.—Distribution of load among load centers of the superpower system for 1925 and 1930.

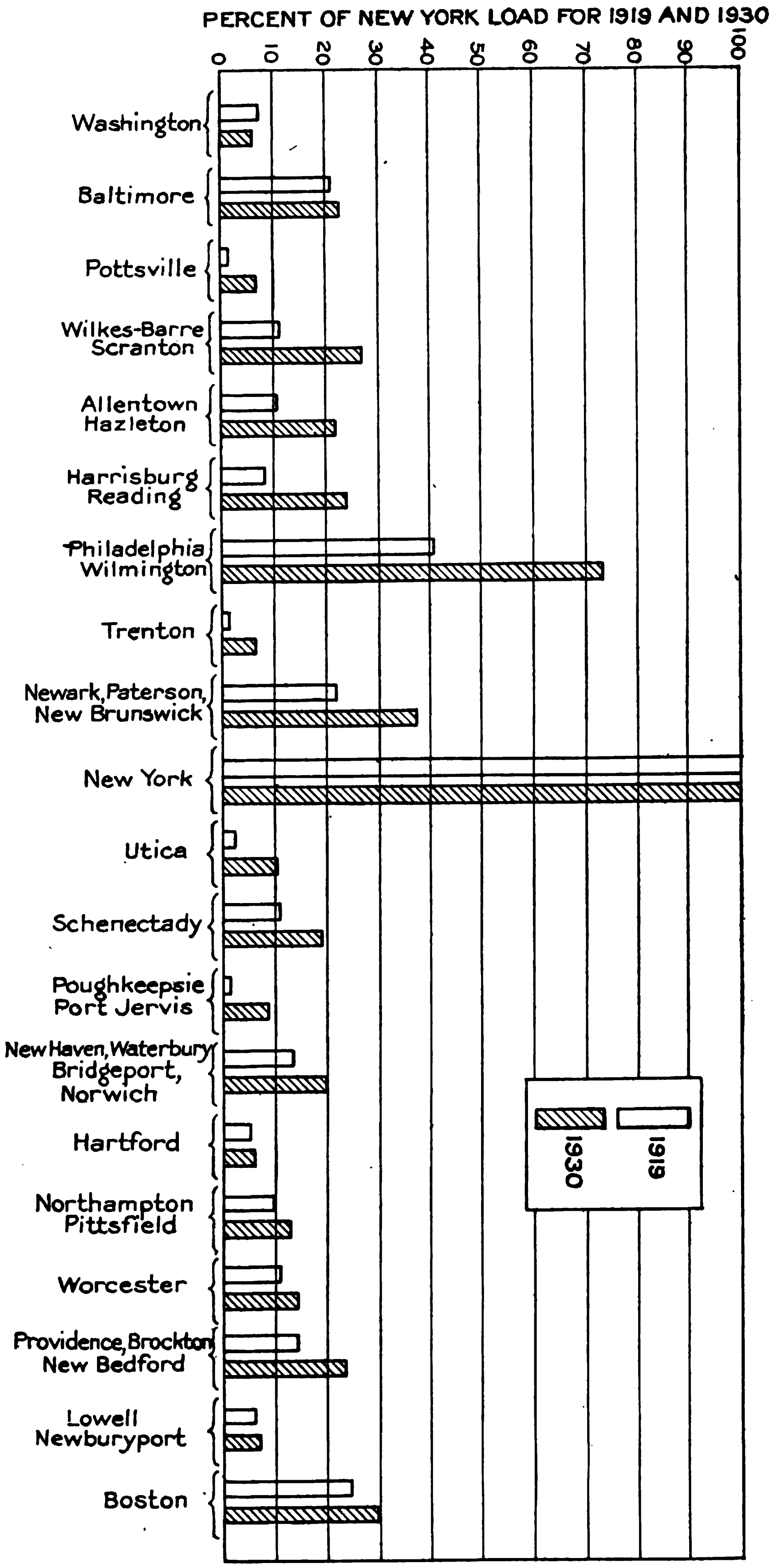

FIGURE 21.—Load at the several load centers in 1919 and 1930, in percentage of load at New York. This diagram shows decentralization of the load through the relatively large growth of heavy-traction railroad and industrial loads. The 20 load centers for 1919 have been increased to 34 for 1930. The first name in each group is the original load center; the others are the additional centers for 1930. The district represented by each group is the same for both years.

FREQUENCY.

The adoption of a standard frequency for the entire country would afford unquestionable advantages. The two frequencies 60 and 25 cycles have become well established throughout the superpower zone. Table 52 is a summary of the energy generated at different frequencies in each geographic division during 1919.

TABLE 52.—*Percentages of energy generated at different frequencies for electric public utilities in the superpower zone in 1919.*

Geographic division.	Demand (thousands of kilowatts).	Output (millions of kilowatt-hours).	Percentage of output generated at different frequencies.		
			25 cycles.	60 cycles.	Other frequencies.
Eastern New England	572.82	1,772.41	19.8	70.0	10.2
Western New England	314.13	921.99	18.8	73.3	7.9
Mohawk	135.87	438.16	8.4	24.2	67.4
Metropolitan	1,165.00	3,866.67	71.6	27.8	.6
Hudson	21.50	60.48	.0	98.1	1.9
Anthracite	185.08	743.06	30.2	66.9	2.9
Southern	660.69	2,498.36	51.1	44.8	4.1
	3,055.09	10,301.13	47.0	46.2	6.8

Table 53 shows the percentages of energy generated at different frequencies in the five most densely populated load centers in the superpower zone—Boston, New York, Philadelphia, Baltimore, and Washington—and in the superpower zone exclusive of these five load centers.

TABLE 53.—*Percentages of energy generated at different frequencies at five principal load centers in superpower zone and in the remainder of the zone.*

	Demand (thousands of kilowatts).	Output (millions of kilowatt-hours).	Percentage of output generated at different frequencies.		
			25 cycles.	60 cycles.	Other frequencies.
Five principal load centers	1,782.76	6,102.54	68.2	28.0	3.8
Remainder of superpower zone	1,272.33	4,198.59	16.2	72.7	11.1

In New York City 84.6 per cent of the energy is generated at 25 cycles, in Baltimore 98.5 per cent, and in Washington 99 per cent. In all other parts of the superpower zone the principal frequency used is 60 cycles.

Table 54 shows the percentages of total capacity at different frequencies in the several geographic divisions of the superpower zone in 1919:

TABLE 54.—*Percentages of total capacity at different frequencies of steam-electric and hydroelectric plants generating electricity for use by electric public utilities in the superpower zone in 1919.*

Geographic division.	Capacity (thousands of kilowatts).			Percentage of total capacity at different frequencies.		
	Steam-electric.	Hydro-electric.	Total.	25 cycles.	60 cycles.	Other frequencies.
Eastern New England	815.7	96.0	911.7	21.8	67.7	10.5
Western New England	369.4	111.5	481.0	15.1	77.3	7.6
Mohawk	58.3	116.2	174.4	10.6	29.1	60.3
Metropolitan	1,629.8	8.7	1,638.5	70.1	27.9	2.0
Hudson	26.8	8.7	35.5	0	97.2	2.8
Anthracite	217.8	5.1	222.9	25.4	68.5	6.1
Southern	882.4	105.3	987.7	53.7	40.7	5.6
	4,000.2	451.5	4,451.7	45.5	46.8	7.7

Of the power-plant capacity in the zone 89.9 per cent is steam-electric and 10.1 per cent is hydroelectric.

The electric street railways are by far the principal users of 25-cycle energy, because 25-cycle rotary converters were developed before the use of 60-cycle converters became practicable.

Figure 22 shows the number of sales and the trend of sales of generating equipment in the superpower zone between 1914 and 1919 for the two frequencies mentioned. Similarly figure 23 shows the electric-utility output at the two frequencies for 1910 to 1919, inclusive. This figure indicates a decided trend toward 60 cycles, both in generator sales and in electric-utility output.

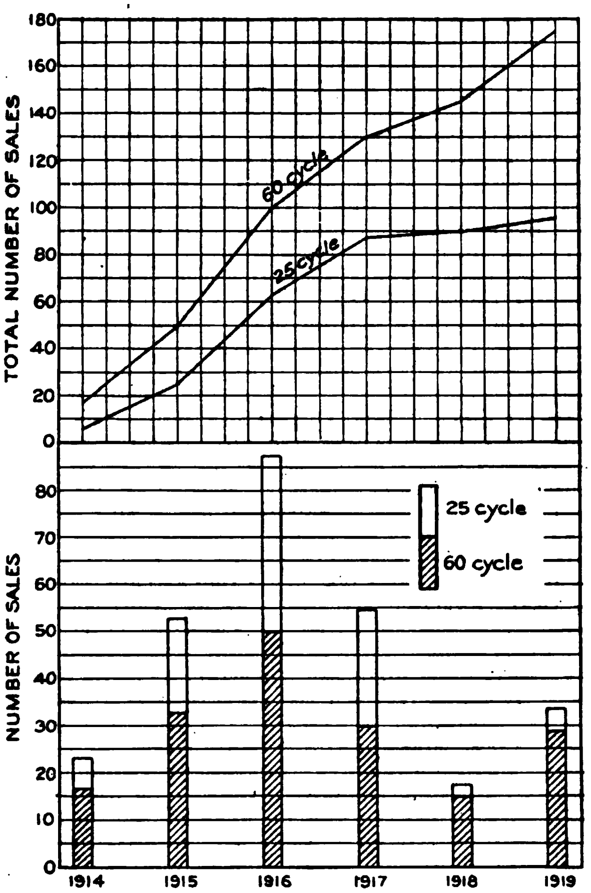

FIGURE 22.—Sales of 25-cycle and 60-cycle generators in the superpower zone, 1914-1919.

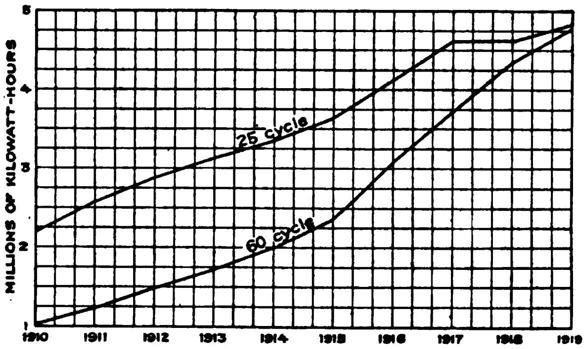

FIGURE 23.—Output of electric utilities in the superpower zone, 1910-1919.

The generator, motor equipment, and transformers for a 60-cycle installation cost, respectively, about 10, 25, and 35 per cent less than those for a 25-cycle installation. A 300,000-kilowatt plant employing 60 cycles rather than 25 cycles would save in its generator equipment and in motors and transformers connected to its distribution system about $7,000,000. Incandescent lamps furnished with 60-cycle energy are free from the flickering that is incident to lower frequencies. On the other hand, for a steel mill, where slow-speed motors are used, and for street railways, where the energy is converted into direct current, the lower frequency can still be used with advantage where a large investment has already been made in equipment. Although 25 cycles has been the frequency used for two of the largest railroad electrifications in the zone it is evident that the trend is toward 60 cycles and that this frequency will eventually predominate. These two frequencies will be interconnected by means of frequency changers as rapidly as economic conditions justify their use.

For long-distance transmission there is a limit beyond which 60 cycles can not be used. A 60-cycle 220,000-volt line can be operated practically to a distance of 350 miles; lower frequencies may be necessary on longer lines.

It is clear that the superpower zone will eventually have an extensive network of interconnected transmission lines, and in order that this network may be established and operated at the least expense it is necessary to fix a standard frequency. The evidence assembled shows that this frequency should be 60 cycles.

ESTIMATED LOAD GROWTH.

Figure 24 shows graphically the past and estimated future load growth for the superpower zone for energy supplied to street railroads, electrified heavy-traction railroads, industries, and domestic consumers. This figure differs from Plate IV, in Appendix B, by the inclusion of the heavy-traction railroad load.

EFFECT OF DIVERSITY AND LOAD FACTOR.

Investigation was made of the diversity existing on November 25, 1919, the day of apparent maximum load for the superpower zone. Seasonal diversity, which is greater than daily diversity, was not taken into account.

There are three distinct diversities in the superpower zone—local diversity, or that which exists between the sum of the peaks of the individual electric public-utility companies as now operated and the peak that would be reached if they were interconnected at their respective load centers; regional diversity, or that which exists between the sum of the peaks of the individual load centers and the peak that would be reached in the entire superpower system if these load centers were interconnected; and total diversity, or that which exists between the sum of the peaks of the individual public-utility companies as now operated and the peak that would be reached in the superpower system if there were complete interconnection throughout the superpower zone.

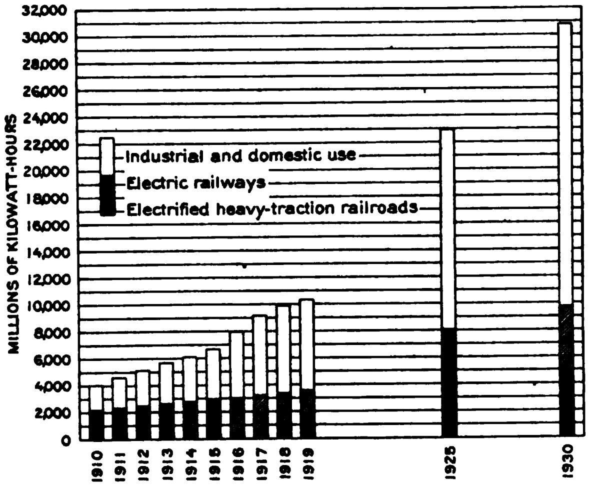

FIGURE 24.—Past and estimated future growth in load for superpower zone, 1910-1930.

The local diversity ranges from zero at Baltimore and Pottsville to 14.4 per cent at the New York load center. The comparatively high local diversity shown for New York on November 25 suggested the further investigation of this load center, where exceptional conditions exist. The following table shows the diversity that existed among the four largest utility companies in New York City on seven days in 1919 and three days in 1920:

TABLE 55.—*Diversity among four utility companies in New York on certain days.*

Date.	Total of nonco-incident peak loads (thousands of kilowatts).	Coincident peak loads (thousands of kilowatts).	Time of coincident peaks.	Diversity factor.
July 22, 1919	563.0	511.1	9 a. m.	1.10
July 23, 1919	569.0	523.0	....do	1.09
July 24, 1919	529.8	508.6	....do	1.04
Nov. 25, 1919	779.4	695.0	5 p. m.	1.12
Dec. 16, 1919	745.5	688.5	....do	1.08
Dec. 17, 1919	763.6	725.1	....do	1.05
Dec. 18, 1919	783.4	741.0	....do	1.06
Dec. 14, 1920	788.3	728.1	....do	1.08
Dec. 15, 1920	800.9	739.4	....do	1.08
Dec. 16, 1920	821.9	779.8	....do	1.05

At certain load centers a large part of the local diversity has been absorbed through interconnection. Utilization of local diversity is not necessarily an attribute of the superpower system. It can be accomplished, as now, by the interconnection of the present electric-utility plants.

Regional diversity as applied to the superpower zone is in general so small as to be of theoretical rather than practical value. Partial regional diversity between the Anthracite division and the Metropolitan and Southern divisions is very marked and will become particularly evident with the growth of the Anthracite load by 1925 and 1930. In the Anthracite division the peak is controlled by the mining industry and occurs in the morning; there is a rapid falling off in load after 3 p. m. A combination of this load with the loads of the Metropolitan and Southern divisions will produce a great saving in power-plant cost over and above the cost of the transmission system necessary to effect the interconnection.

Table 56 shows the local diversity at each load center, the regional diversity between load centers, and the total diversity in 1919.

TABLE 56.—*Diversity in superpower zone, 1919.*

Geographic division and load center.	Noncoincident peak loads of utility companies (thousands of kilowatts).	Peak at load center if utility plants had been interconnected (thousands of kilowatts).	Local diversity factor.	Demand at load centers at time of superpower-zone peak (thousands of kilowatts).	Regional diversity factor.	Total diversity factor.
	A	B	C	D	E	F
Eastern New England:						
Boston	208.48	190.64	1.09	190.64		
Lowell	34.53	32.27	1.07	24.76		
Providence	132.10	121.07	1.09	121.07		
Worcester	91.25	85.51	1.07	85.51		
Western New England:						
Hartford	52.38	49.93	1.05	49.93		
New Haven	105.96	98.85	1.07	98.85		
Northampton	66.22	66.04	1.00	66.04		
Mohawk:						
Utica	22.83	22.34	1.02	19.76		
Albany	87.70	85.20	1.03	85.20		
Metropolitan:						
New York	863.78	755.25	1.14	755.25		
Newark	155.18	154.03	1.01	154.03		
Hudson:						
Poughkeepsie	11.96	11.50	1.04	10.37		
Anthracite:						
Pottsville	8.00	8.00	1.00	6.75		
Allentown	96.35	95.26	1.01	73.90		
Wilkes-Barre	50.01	45.85	1.09	44.89		
Southern:						
Trenton	5.15	4.90	1.05	3.99		
Harrisburg	51.84	51.03	1.02	51.03		
Philadelphia	297.24	286.72	1.04	286.72		
Baltimore	118.78	118.78	1.00	118.10		
Washington	55.20	54.22	1.02	52.96		
Superpower zone	2,514.94	2,337.39	....	2,299.75	1.02	1.09

In this report diversity has been used only as an aid to determine the capacity that would have been required for a superpower system in 1919. The estimated capacity required for 1925 and 1930 is arrived at through a study of the trend of load factor for each of the individual load centers.

Figure 25 shows the trend of load factor in each geographic division of the superpower zone during the period 1910 to 1919, inclusive. The curve for the zone as a whole is extended to indicate estimated load factor on utility systems in 1930 (curve B). The steady improvement in load factor shown by these curves is due to three causes—interconnection of utility plants, increase of off-peak load, and growth of industrial demand. The greatest improvement in load factor is realized where the ratio of industrial load to lighting load is high. Where the industrial load is small compared with the lighting load, as in New York City, there is little opportunity for improvement in load factor.

The effect of the war in increasing the load factor in 1917 and 1918 by introducing overtime and night work in many of the industries is very apparent. In extending the curves to indicate future improvement in load factor this abnormal increase has been discounted.

Curve A in this figure shows the load factor assumed for superpower operation. This curve is determined by adding the heavy-traction railroad load to that of the street railroads and electric utilities, represented by curve B. With the expected growth of industrial and heavy-traction loads it would seem that the estimated load factor of 47 per cent for the entire superpower zone in 1930 is conservative.

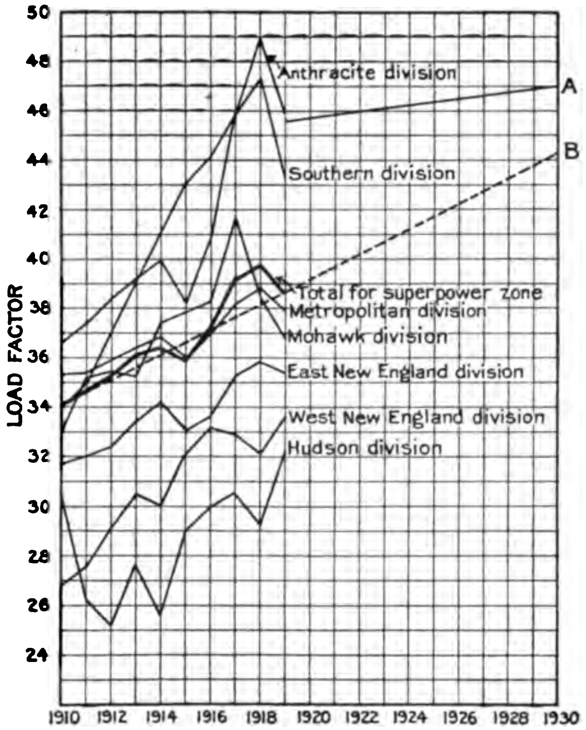

FIGURE 25.—Trend of load factor for superpower zone. A, Load factor inclusive of electrified heavy-traction railroads; B, load factor for electric utilities and street railroads.

PHYSICAL DATA.

PRODUCTION FACILITIES.

Table 60, giving the total power-plant capacity and output for the superpower system for 1919, 1925, and 1930, shows the following division of this capacity and output between steam-electric plants and hydroelectric plants:

TABLE 57.—*Capacity and output of steam-electric and hydroelectric plants, 1919, 1925, and 1930, in percentages.*

Year	Steam-electric.		Hydroelectric.	
	Capacity.	Output.	Capacity.	Output.
1919	81.8	78.2	18.2	21.8
1925	83.5	81.5	16.5	18.5
1930	81.5	79.2	18.5	20.8

The division of capacity and output between new power plants and present power plants retained for the superpower system is as follows:

TABLE 58.—*Capacity and output of new and retained plants, in percentages.*

Year.	New plants.			Existing plants retained.		
	Capacity.	Output.	Annual capacity factor.	Capacity.	Output.	Annual capacity factor.
1919	44.8	69.0	63.0	55.2	31.0	22.7
1925	49.8	74.0	64.6	50.2	26.0	22.8
1930	61.4	82.1	60.3	38.6	17.9	20.2

The higher efficiency under the superpower system is largely attained by operating the new power plants at high annual capacity factors and by using the older plants to carry peak load at low annual capacity factors.

TABLE 59.—*Weighted average capacity of the power plants of the superpower system, in kilowatts.*

	1925	1930
Hydroelectric plants retained	2,860	2,860
Steam-electric plants retained	44,600	44,600
Weighted average of old plants retained	14,300	14,300
New hydroelectric plants	36,100	30,000
New steam-electric plants	180,000	218,000
Weighted average of new plants	103,200	94,000
Weighted average of all plants	25,100	29,900

The average capacity of the steam-electric plants in operation in the electric utilities in 1919 was 10,000 kilowatts, and the average capacity of the steam-electric plants retained is 44,600 kilowatts, a gain made by eliminating the smaller and less efficient plants. The program of construction for new steam-electric plants shows an average capacity of plant in 1930 of more than twenty times that of the steam-electric plants serving electric public utilities in 1919.

TABLE 60.—*Power-plant capacity for the superpower system, 1919, 1925, and 1930.*

Geographic division.	Plant capacity (thousands of kilowatts).	Peak demand (thousands of kilowatts).	Plant reserve (thousands of kilowatts).	Output (millions of kilowatt-hours).	Capacity factor (per cent).
1919.					
Eastern New England:					
Present steam-electric plants	514.6			516.0	11.5
New steam-electric plants	360.0			2,366.0	75.0
	874.6			2,882.0	37.6
Present hydroelectric plants	96.0			269.0	32.0
New hydroelectric plants					
	96.0			269.0	32.0
All plants	970.6	842.7	127.8	3,151.0	37.0
Western New England:					
Present steam-electric plants	171.8			77.0	5.1
New steam-electric plants	270.0			1,091.0	46.0
	441.8			1,168.0	30.1
Present hydroelectric plants	111.5			340.0	34.8
New hydroelectric plants	50.0			230.0	52.5
	161.5			570.0	40.3
All plants	603.3	468.4	134.6	1,738.0	32.9

TABLE 60.—*Power-plant capacity for the superpower system, 1919, 1925, and 1930*—Continued.

Geographic division.	Plant capacity (thousands of kilowatts).	Peak demand (thousands of kilowatts).	Plant reserve (thousands of kilowatts).	Output (millions of kilowatt-hours).	Capacity factor (per cent).
1919—Continued.					
Mohawk-Hudson:					
Present steam-electric plants	45.7			20.0	5.0
New steam-electric plants	180.0			605.0	38.3
	225.7			625.0	31.6
Present hydroelectric plants	124.9			361.0	32.9
New hydroelectric plants	100.0			380.0	43.3
	224.9			741.0	37.6
All plants	450.6	321.7	129.3	1,366.0	34.5
Metropolitan:					
Present steam-electric plants	1,130.5			2,960.0	30.0
New steam-electric plants	[a] 240.0			[b] 2,088.0	51.3
	1,370.5			5,048.0	33.5
Present hydroelectric plants	8.7			22.0	28.8
New hydroelectric plants	183.0			850.0	53.0
	191.7			872.0	52.0
All plants	1,562.2	1,436.0	([c])	5,920.0	35.8
Anthracite:					
Present steam-electric plants	159.5			537.0	38.4
New steam-electric plants	[d] 450.0			[e] 1,950.0	75.0
	609.5			2,487.0	65.5
Present hydroelectric plants	5.1			16.0	35.9
New hydroelectric plants					
	5.1			16.0	35.9
All plants	614.6	653.4	([c])	2,503.0	65.3
Southern:					
Present steam-electric plants	654.5			579.0	10.1
New steam-electric plants	450.0			2,923.0	74.2
	1,104.5			3,502.0	36.2
Present hydroelectric plants	105.3			542.0	58.8
New hydroelectric plants	245.0			1,434.0	66.8
	350.3			1,976.0	64.3
All plants	1,454.8	1,131.8	([c])	5,478.0	42.9
Superpower zone:					
Present steam-electric plants	2,676.6			4,689.0	20.0
New steam-electric plants	1,950.0			11,023.0	64.5
	4,626.6			15,712.0	38.8
Present hydroelectric plants	451.5			1,550.0	39.2
New hydroelectric plants	578.0			2,894.0	57.0
	1,029.5			4,444.0	49.3
All plants	5,656.1	4,854.0	802.5	20,156.0	40.5

[a] Does not include the portion of the Pittston plant capacity chargeable to the Metropolitan division.

[b] Includes a portion of the output from the Pittston plant.

[c] Joint reserve for Metropolitan, Anthracite, and Southern divisions, 1919, is 410,800 kilowatts.

[d] Includes the total Pittston plant capacity.

[e] Is not the total output of the Pittston plant.

TABLE 60.—*Power-plant capacity for the superpower system, 1919, 1925, and 1930*—Continued.

Geographic division.	Plant capacity (thousands of kilowatts).	Peak demand (thousands of kilowatts).	Plant reserve (thousands of kilowatts).	Output (millions of kilowatt-hours).	Capacity factor (per cent).
1919—Continued.					
Superpower zone—Continued.					
Present plants retained	3,128.1			6,239.0	22.7
New plants proposed	2,528.0			13,917.0	62.9
Steam-electric ... per cent of total	81.8			78.2	
Hydroelectric ... do	18.2			21.8	
1925.					
Eastern New England:					
Present steam-electric plants	514.6			516.0	11.5
New steam-electric plants	450.0			2,811.0	71.2
	964.6			3,327.0	39.4
Present hydroelectric plants	96.0			269.0	32.0
New hydroelectric plants					
	96.0			269.0	32.0
All plants	1,060.6	918.0	142.5	3,596.0	38.7
Western New England:					
Present steam-electric plants	171.8			77.0	5.1
New steam-electric plants	300.0			1,223.0	46.5
	471.8			1,300.0	31.4
Present hydroelectric plants	111.5			340.0	34.8
New hydroelectric plants	50.0			230.0	52.5
	161.5			570.0	40.3
All plants	633.3	513.0	120.0	1,870.0	33.7
Mohawk-Hudson:					
Present steam-electric plants	45.7			20.0	5.0
New steam-electric plants	240.0			1,039.0	49.5
	285.7			1,059.0	49.5
Present hydroelectric plants	124.9			361.0	32.9
New hydroelectric plants	100.0			380.0	43.3
	224.9			741.0	37.6
All plants	510.6	415.0	96.0	1,800.0	40.2
Metropolitan:					
Present steam-electric plants	1,130.5			2,960.0	30.0
New steam-electric plants	[a] 390.0			[b] 3,508.0	67.0
	1,520.5			6,468.0	39.4
Present hydroelectric plants	8.7			22.0	28.8
New hydroelectric plants	183.0			850.0	53.0
	191.7			872.0	52.0
	1,712.2	1,730.0	(c)	7,340.0	40.8
Anthracite:					
Present steam-electric plants	159.5			537.0	38.4
New steam-electric plants	[d] 450.0			[e] 1,735.0	75.0
	609.5			2,272.0	65.5

[a] Does not include the portion of the Pittston plant capacity chargeable to the Metropolitan division.
[b] Includes a portion of the output from the Pittston plant.
[c] Joint reserve for Metropolitan, Anthracite, and Southern divisions, 1925, is 285,000 kilowatts.
[d] Includes the total Pittston plant capacity.
[e] Is not the total output of the Pittston plant.

TABLE 60.—*Power-plant capacity for the superpower system, 1919, 1925, and 1930*—Continued.

Geographic division.	Plant capacity (thousands of kilowatts).	Peak demand (thousands of kilowatts).	Plant reserve (thousands of kilowatts).	Output (millions of kilowatt-hours).	Capacity factor (per cent).
1925—Continued.					
Anthracite—Continued.					
Present hydroelectric plants	5.1			16.0	35.9
New hydroelectric plants					
	5.1			16.0	35.9
All plants	614.6	549.0	(a)	2,288.0	65.3
Southern:					
Present steam-electric plants	654.5			579.0	10.1
New steam-electric plants	690.0			4,365.0	72.2
	1,344.5			4,944.0	42.0
Present hydroelectric plants	105.3			542.0	58.8
New hydroelectric plants	245.0			1,434.0	66.8
	350.0			1,976.0	64.3
All plants	1,694.8	1,477.0	(a)	6,920.0	46.7
Superpower zone:					
Present steam-electric plants	2,676.6			4,689.0	20.0
New steam-electric plants	2,520.0			14,681.0	66.4
	5,196.6			19,370.0	42.5
Present hydroelectric plants	451.5			1,550.0	39.2
New hydroelectric plants	578.0			2,894.0	57.0
	1,029.5			4,444.0	49.3
All plants	6,226.1	5,602.0	624.5	23,814.0	43.7
Present plants retained	3,128.1			6,239.0	22.8
New plants proposed	3,098.0			17,575.0	64.6
Steam-electric ... per cent of total	83.5			81.5	
Hydroelectric ... do	16.5			18.5	
1930.					
Eastern New England:					
Present steam-electric plants	514.6			528.0	11.7
New steam-electric plants	810.0			4,148.0	58.3
	1,324.6			4,676.0	40.3
Present hydroelectric plants	96.0			269.0	32.0
New hydroelectric plants					
	96.0			269.0	32.0
All plants	1,420.6	124.3	177.5	4,945.0	39.6
Western New England:					
Present steam-electric plants	171.8			77.0	5.1
New steam-electric plants	390.0			1,237.0	36.2
	561.8			1,314.0	26.7
Present hydroelectric plants	111.5			340.0	34.8
New hydroelectric plants	165.0			760.0	52.5
	276.5			1,100.0	45.3
All plants	838.3	652.0	186.0	2,414.0	32.8
Mohawk-Hudson:					
Present steam-electric plants	45.7			20.0	5.0
New steam-electric plants	360.0			1,312.0	41.5
	405.7			1,332.0	37.4

[a] Joint reserve for Metropolitan, Anthracite, and Southern divisions, 1925, is 265,000 kilowatts.

TABLE 60.—*Power-plant capacity for the superpower system, 1919, 1925, and 1930*—Continued.

Geographic division.	Plant capacity (thousands of kilowatts).	Peak demand (thousands of kilowatts).	Plant reserve (thousands of kilowatts).	Output (millions of kilowatt-hours).	Capacity factor (per cent).
1930—Continued.					
Mohawk-Hudson—Continued.					
Present hydroelectric plants	124.9	...	...	341.0	31.1
New hydroelectric plants	150.0	...	...	900.0	68.3
	274.9	...	...	1,241.0	51.7
All plants	680.6	591.0	90.0	2,573.0	43.0
Metropolitan:					
Present steam-electric plants	1,130.5	...	...	2,276.0	23.0
New steam-electric plants	[a]750.0	...	...	[b]5,812.0	67.5
	1,880.5	...	...	8,088.0	40.7
Present hydroelectric plants	8.7	...	...	22.0	28.8
New hydroelectric plants	350.0	...	...	1,240.0	40.5
	358.7	...	...	1,262.0	40.2
All plants	2,239.2	2,156.0	([c])	9,350.0	40.6
Anthracite:					
Present steam-electric plants	159.5	...	...	537.0	51.0
New steam-electric plants	[d]600.0	...	...	[a]2,571.0	75.0
	759.5	...	...	3,108.0	67.3
Present hydroelectric plants	5.1	...	...	16.0	35.9
New hydroelectric plants	...	...	...	...	...
	5.1	...	...	16.0	35.9
All plants	764.6	785.0	([c])	3,124.0	67.1
Southern:					
Present steam-electric plants	654.5	...	...	579.0	10.1
New steam-electric plants	1,020.0	...	...	6,219.0	69.5
	1,674.5	...	...	6,798.0	46.2
Present hydroelectric plants	105.3	...	...	542.0	58.8
New hydroelectric plants	385.0	...	...	2,180.0	64.5
	490.3	...	...	2,722.0	63.4
All plants	2,164.8	1,995.0	([c])	9,520.0	50.0
Superpower zone:					
Present steam-electric plants	2,676.6	...	...	4,017.0	17.1
New steam-electric plants	3,930.0	...	...	21,299.0	61.8
	6,606.0	...	...	25,316.0	43.7
Present hydroelectric plants	451.5	...	...	1,530.0	38.6
New hydroelectric plants	1,050.0	...	...	5,080.0	55.2
	1,501.5	...	...	6,610.0	50.3
All plants	8,108.1	7,422.0	676.5	31,926.0	45.0
Present plans retained	3,128.1	...	...	5,547.0	20.2
New plants proposed	4,980.0	...	...	26,379.0	60.3
Steam-electric ... per cent of total	81.5	...	...	79.2	...
Hydroelectric ... do	18.5	...	...	20.8	...

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[a] Does not include the portion of the Pittston plant capacity chargeable to the Metropolitan division.
[b] Includes a portion of the output from the Pittston plant.
[c] Joint reserve for Metropolitan, Anthracite, and Southern divisions 1930, is 233,000 kilowatts.
[d] Includes the total Pittston plant capacity.
[e] Is not the total output of the Pittston plant.

TRANSMISSION LINES.

Table 61 gives the mileage of the transmission lines required for the superpower system for 1919, 1925, and 1930.

Plates II and III (p. 14) show the proposed transmission lines for 1925 and 1930, respectively, and Plate III shows in addition proposed lines from the St. Lawrence and Niagara for 1932. These plates also show the approximate location for proposed new steam-electric and hydroelectric plants.

Reliable service is insured by the interconnecting network, as each principal load center is served by eight incoming lines, four from each direction, and a few favorably located load centers have even more.

TABLE 61.—*Transmission lines for superpower zone in 1919, 1925, and 1930, in miles.*

Year and geographic division.	220,000-volt.			110,000-volt.		
	Route.	Tower.	Circuit.	Route.	Tower.	Circuit.
1919.						
Eastern New England	0	0	0	207	207	414
Western New England	0	0	0	264	415	630
Mohawk-Hudson	0	0	0	237	317	634
Metropolitan	102	204	408	283	393	786
Anthracite	35	70	70	59	111	222
Southern	123	246	492	314	463	926
Superpower zone	260	520	970	1,364	1,806	3,612
1925.						
Eastern New England	0	0	0	262	262	524
Western New England	0	0	0	264	315	630
Mohawk-Hudson	0	0	0	237	317	634
Metropolitan	102	204	408	283	393	786
Anthracite	35	70	70	70	133	266
Southern	123	246	492	314	463	926
Superpower zone	260	520	970	1,430	1,883	3,766
1930.						
Eastern New England	0	0	0	262	262	524
Western New England	0	0	0	421	601	1,202
Mohawk-Hudson	0	0	0	262	418	836
Metropolitan	102	204	408	302	444	888
Anthracite	35	70	70	70	140	280
Southern	123	246	492	334	483	966
Superpower zone	260	520	970	1,651	2,348	4,696

SUBSTATIONS.

In Table 62 the transformer capacity does not include that installed in base-load steam-electric plants, and the synchronous-condenser capacity does not include the condenser effect of generators used as such, or of motor generator sets in the heavy-traction railroad substations.

TABLE 62.—*Substation capacity for the superpower system in 1919, 1925, and 1930, in thousands of kilovolt-amperes.*

Geographic division.	Transformers. 220,000-volt primary.	Transformers. 110,000-volt primary.	Synchronous condensers.	Frequency changers.
1919.				
Eastern New England	0	325	150	0
Western New England	0	125	105	0
Mohawk-Hudson	0	300	45	30
Metropolitan	800	483	135	0
Anthracite	125	425	90	0
Southern	200	495	165	0
Superpower zone	1,125	2,153	690	30
1925.				
Eastern New England	0	475	150	0
Western New England	0	375	105	0
Mohawk-Hudson	0	350	45	30
Metropolitan	850	633	135	0
Anthracite	50	500	90	0
Southern	300	595	165	0
Superpower zone	1,200	2,928	690	30
1930.				
Eastern New England	0	550	180	0
Western New England	0	590	135	0
Mohawk-Hudson	0	475	60	60
Metropolitan	1,050	935	180	0
Anthracite	75	675	150	0
Southern	325	935	195	0
Superpower zone	1,450	4,160	900	60

FUEL REQUIREMENT.

Table 65 gives the fuel requirement for the superpower system for 1919, 1925, and 1930. The estimated fuel saving by the superpower system to the electric public utilities is as follows:

TABLE 63.—*Fuel saving by superpower system to electric public utilities.*

	1919	1925	1930
Coal that would be required at 1919 fuel rate for electric power produced by steam .... short tons	24,600,000	29,600,000	39,700,000
Coal required for superpower operation .... do	14,103,000	16,591,000	20,551,000
Annual saving by superpower operation .... do	10,497,000	13,001,000	19,149,000
Average cost per ton of coal delivered to superpower system	$4.37	$5.25	$5.25
Value of fuel saving	$45,872,000	$68,200,000	$100,500,000

For independent operation the production of power by water has been taken at 2,100,000,000 kilowatt-hours for 1925 and 2,800,000,000 kilowatt-hours for 1930. These figures are based on growth of water power for the electric utilities indicated by data collected by the United States Bureau of the Census.

If in 1930 the superpower system were supplied with energy produced entirely from coal with the exception of that from existing hydroelectric plants the coal required would amount to 23,184,100 short tons, and the fuel saving would be 2,633,100 tons less than that effected by the proposed arrangement of superpower facilities for 1930.

TABLE 64.—*Fuel rate for superpower operation and rate under independent operation in 1919, in pounds of coal per kilowatt-hour generated.*

	1919	1925	1930
Superpower operation:			
New steam-electric plants	1.47	1.45	1.43
Retained steam-electric plants	2.54	2.54	2.64
Weighted average, steam-electric plants	1.80	1.71	1.62
Independent operation (1919 performance of electric utilities)	2.73	2.73	2.73

The average cost of fuel delivered to the new base-load steam-electric plants is lower than that for existing steam-electric plants because of the advantageous locations that can be selected for the new plants. (See Appendix F.) This difference is particularly marked in the comparison of the unit fuel cost for the electric utilities for 1919 (see p. 48) and that of the hypothetical superpower system for 1919, for which the cost of coal at the mine and the railroad freight rate have been assumed to be the same, the resulting cost to the utilities being $5.35 per short ton, whereas that to the superpower system is $4.37 per ton. For the same reason, despite the higher freight rates charged against coal to the superpower system for 1925 and 1930, the resulting unit cost to the superpower system is less than that to the electric utilities for 1919.

By the use of St. Lawrence power to the extent of 600,000 kilowatts at a load factor of 80 per cent in the Eastern New England, Western New England, and Mohawk-Hudson divisions in 1932 the annual coal requirement will be 2,234,000 tons less than the quantity which would be used were this amount of power generated by new steam-electric plants. By the use of Niagara power to the extent of 300,000 kilowatts at a load factor of 80 per cent in the Metropolitan division in 1932 the annual coal requirement will be 1,204,000 tons less than the quantity which would be used were this amount of power generated by new steam-electric plants.

TABLE 65.—*Fuel requirements for superpower system for 1919, 1925, and 1930.*

Geographic division.	Coal per kilowatt-year of capacity (short tons).	Total quantity of coal per year (thousands of short tons).	Cost per short ton delivered.	Total annual cost.	Coal per kilowatt-hour (pounds).
1919.					
Eastern New England:					
Present plants	1.31	673.2	$6.15	$4,132,000	2.61
New plants	3.92	1,412.0	6.10	8,620,000	1.20
	2.39	2,085.2	6.11	12,752,000	1.44
Western New England:					
Present plants	.84	144.8	5.88	851,000	3.76
New plants	2.70	729.0	5.67	4,130,000	1.33
	1.97	873.8	5.70	4,981,000	1.50
Mohawk-Hudson:					
Present plants	1.12	51.2	5.32	272,000	5.12
New plants	2.28	410.0	5.32	2,180,000	1.35
	2.04	461.2	5.32	2,452,000	1.47
Metropolitan:					
Present plants	2.80	3,170	5.22	16,550,000	2.14
New plants	2.99	[a] 1,625	5.22	5,878,000	1.33
	2.84	4,795	5.22	22,428,000	1.93
Anthracite:					
Present plants	6.80	1,085	2.53	2,752,000	4.04
New plants	5.92	[a] 1,759.0	2.35	4,135,000	1.80
	6.17	2,844.0	2.41	6,887,000	2.15

[a] Includes a portion of the coal burned in the Pittston plant.

TABLE 65.—*Fuel requirements for superpower system for 1919, 1925, and 1930*—Continued.

Geographic division.	Coal per kilowatt-year of capacity (short tons).	Total quantity of coal per year (thousands of short tons).	Cost per short ton delivered.	Total annual cost.	Coal per kilowatt-hour (pounds).
1919—Continued.					
Southern:					
Present plants	1.29	845.8	$5.05	$4,270,000	2.93
New plants	4.88	2,198.0	3.66	8,045,000	1.50
	2.76	3,043.8	4.05	12,315,000	1.73
Superpower zone:					
Present plants	2.23	5,969.8	4.84	28,827,000	2.54
New plants	4.16	8,133.0	4.06	32,988,000	1.47
	3.05	14,102.8	4.37	61,815,000	1.80
1925.					
Eastern New England:					
Present plants	1.29	665.3	7.40	4,928,300	2.58
New plants	3.74	1,679.0	7.42	12,435,000	1.19
	2.44	2,344.3	7.40	17,363,300	1.41
Western New England:					
Present plants	.84	144.8	7.10	1,028,900	3.76
New plants	2.72	816.0	6.86	5,600,000	1.33
	2.04	960.8	6.90	6,628,900	1.48
Mohawk-Hudson:					
Present plants	1.12	51.2	6.33	324,000	5.14
New plants	2.88	692.0	6.33	4,380,000	1.33
	2.60	743.2	6.33	4,704,000	1.40
Metropolitan:					
Present plants	2.80	3,170.0	6.25	19,800,000	2.14
New plants	3.84	[a]2,598.0	6.25	12,190,000	1.32
	3.06	5,768.0	6.25	31,990,000	1.68
Anthracite:					
Present plants	6.80	1,085.0	2.81	3,046,000	4.04
New plants	5.92	[a]1,565.0	2.57	4,025,000	1.80
	6.17	2,650.0	2.65	7,071,000	2.15
Southern:					
Present plants	1.29	845.8	5.89	4,979,000	2.93
New plants	4.75	3,279.0	4.42	14,480,000	1.50
	3.06	4,124.8	4.72	19,459,000	1.67
Superpower zone:					
Present plants	2.23	5,962.1	5.72	34,106,200	2.54
New plants	4.23	10,629.0	5.00	53,110,000	1.45
	3.20	16,591.1	5.25	87,216,200	1.71
1930.					
Eastern New England:					
Present plants	1.30	673.2	7.43	4,995,000	2.55
New plants	3.10	2,512.0	7.42	18,610,000	1.21
	2.41	3,185.2	7.42	23,605,000	1.37
Western New England:					
Present plants	.84	144.8	7.10	1,029,000	3.76
New plants	2.17	846.0	6.87	5,810,000	1.37
	1.76	990.8	6.90	6,839,000	1.51

[a] Includes a portion of the coal burned in the Pittston plant.

TABLE 65.—*Fuel requirements for superpower system for 1919, 1925, and 1930*—Continued.

Geographic division.	Coal per kilowatt-year of capacity (short tons).	Total quantity of coal per year (thousands of short tons).	Cost per short ton delivered.	Total annual cost.	Coal per kilowatt-hour (pounds).
1930—Continued.					
Mohawk-Hudson:					
Present plants	1.12	51.2	$6.33	$324,000	5.14
New plants	2.47	888.0	6.33	5,620,000	1.35
	2.31	939.2	6.33	5,944,000	1.41
Metropolitan:					
Present plants	2.23	2,522.0	6.25	15,763,000	2.22
New plants	3.86	[a]4,131.0	6.25	21,300,000	1.31
	2.88	6,653.	6.25	37,063,000	1.61
Anthracite:					
Present plants	6.80	1, 85.0	2.81	3,046,000	4.04
New plants	5.92	[a]2,316.0	2.57	5,948,000	1.80
	6.10	3,401.0	2.63	8,994,000	2.07
Southern:					
Present plants	1.29	845.8	5.89	4,979,000	2.93
New plants	4.44	4,536.0	4.57	20,670,000	1.46
	3.21	5,381.8	4.77	25,649,000	1.59
Superpower zone:					
Present plants	1.98	5,322.0	5.67	30,136,000	2.64
New plants	3.88	15,229.0	5.11	77,958,000	1.43
	3.11	20,551.0	5.25	108,094,000	1.62

[a] Includes a portion of the coal burned in the Pittston plant.

INVESTMENT COST.

The total investment cost for the facilities of the superpower system for 1919, 1925, and 1930 is given in Table 68. The unit cost is shown below; the figures for the retained plants represent reproduction cost in midyear of 1919.

TABLE 66.—*Unit investment cost of superpower system per kilowatt of installed plant capacity.*

	1919	1925	1930
New steam-electric plants	$112.00	$110.60	$109.50
New hydroelectric plants	151.90	151.90	151.30
Average, new plants	121.10	118.40	118.25
Retained steam-electric plants	123.00	123.00	123.00
Retained hydroelectric plants	193.60	193.60	193.60
Average, retained plants	133.00	133.00	133.00
Average, all plants	127.80	125.80	125.00

The greater unit cost of the plants retained is the result of their smaller individual capacity. The new hydroelectric plants for the superpower system are to be located only at the most economical sites and constructed largely to carry peak loads, and therefore they show a lower unit investment cost.

TABLE 67.—*Unit investment cost per kilowatt of demand for all facilities of superpower system.*

	1919	1925	1930
Power plants	$149.00	$140.00	$136.80
Transmission system	16.00	15.40	14.05
	165.00	155.40	150.85

The reproduction cost of the power plants of the electric utilities in 1919 was $598,277,000, or $196 per kilowatt of demand.

The new money required for the superpower project is $453,143,000 by 1925 and $693,218,000 by 1930, thus making it necessary to raise about $90,600,000 annually for the first five years and $48,000,000 annually for the succeeding five-year period. The early installation of the transmission network is responsible for the higher annual requirement for the first five years. This expenditure, however, is justified by the saving that will result through interconnection.

If the increase in demand to 1930 were provided for by independent systems such as were in existence in 1919, a total of about $856,000,000 would have to be expended, requiring financing to the extent of about $85,600,000 annually. Accordingly, the construction of the superpower system should be accomplished with a saving in investment cost of about $163,000,000 during the next 10 years.

TABLE 68.—*Investment cost for the superpower system for 1919, 1925, and 1930, in thousands of dollars.*

	Eastern New England.	Western New England.	Mohawk-Hudson.	Metropolitan.	Anthracite.	Southern.	Superpower zone.
1919.							
Present steam-electric plants	66,235	24,550	7,200	129,105	22,586	79,543	329,219
New steam-electric plants	41,100	29,890	20,920	[a] 43,570	[a] 33,000	50,035	218,515
	107,335	54,440	28,120	172,675	55,586	129,578	547,734
Present hydroelectric plants	16,501	16,713	26,135	2,550	1,265	23,963	87,127
New hydroelectric plants	....	9,000	20,124	25,700	....	33,000	87,824
	16,501	25,713	46,259	28,250	1,265	56,963	174,951
All power plants	123,836	80,153	74,379	200,925	56,851	186,541	722,685
Transmission lines	4,131	6,343	6,108	13,345	3,635	15,009	48,571
Substations	3,656	1,902	3,149	10,955	3,253	6,183	29,098
Transmission system	7,787	8,245	9,257	24,300	6,888	21,192	77,669
Total investment cost	131,623	88,398	83,636	225,225	63,739	207,733	800,354
Debit or credit to other divisions	....	....	−3,800	+3,800	+2,655	−2,655	....
Total investment cost to division	131,623	88,398	79,836	229,025	66,394	205,078	800,354
Investment made as of midyear, 1919	82,736	41,263	33,335	131,655	23,851	103,506	416,346
New money required	48,887	47,135	46,501	97,370	42,543	101,572	384,008
1925.							
Present steam-electric plants	66,235	24,550	7,200	129,105	22,586	79,543	329,219
New steam-electric plants	50,700	33,100	26,850	[a] 62,700	[a] 29,420	76,120	278,890
	116,935	57,650	34,050	191,805	52,006	155,663	608,109
Present hydroelectric plants	16,501	16,713	26,135	2,550	1,265	23,963	87,127
New hydroelectric plants	....	9,000	20,124	25,700	....	33,000	87,824
	16,501	25,713	46,259	28,250	1,265	56,963	174,951
All power plants	133,436	83,363	80,309	220,055	53,271	212,626	783,060

[a] Includes a portion of the Pittston plant investment.

TABLE 68.—*Investment cost for the superpower system for 1919, 1925, and 1930, in thousands of dollars*—Continued.

	Eastern New England.	Western New England.	Mohawk-Hudson.	Metropolitan.	Anthracite.	Southern.	Superpower zone.
1925—Continued.							
Transmission lines	5, 186	6, 346	6, 108	13, 345	4, 085	15, 009	50, 079
Substations	5, 102	3, 655	3, 226	12, 436	4, 163	7, 768	36, 350
Transmission system	10, 288	10, 001	9, 334	25, 781	8, 248	22, 777	86, 429
Total investment cost	143, 724	93, 364	89, 643	245, 836	61, 519	235, 403	869, 489
Debit or credit to other divisions	....	+5, 980	−780	−5, 200	+1, 435	−1, 435	....
Total investment cost to division	143, 724	99, 344	88, 863	240, 636	62, 954	233, 968	869, 489
Investment made as of midyear, 1919	82, 736	41, 263	33, 335	131, 655	23, 851	103, 506	416, 346
New money required	60, 988	58, 081	55, 528	108, 981	39, 103	130, 462	453, 143
1930.							
Present steam-electric plants	66, 235	24, 550	7, 200	129, 105	22, 586	79, 543	329, 219
New steam-electric plants	91, 750	42, 280	39, 195	[a] 103, 100	[a] 42, 800	111, 050	430, 175
	157, 985	66, 830	46, 395	232, 205	65, 386	190, 593	759, 394
Present hydroelectric plants	16, 501	16, 713	26, 135	2, 550	1, 265	23, 963	87, 127
New hydroelectric plants	....	29, 000	38, 350	51, 500	....	40, 000	158, 850
	16, 501	45, 713	64, 485	54, 050	1, 265	63, 963	245, 977
All power plants	174, 486	112, 543	110, 880	286, 255	66, 651	254, 556	1, 013, 535
Transmission lines	5, 186	11, 840	7, 956	14, 369	4, 310	16, 440	60, 101
Substations	5, 730	5, 612	4, 371	14, 606	4, 765	9, 008	44, 092
Transmission system	10, 916	17, 452	12, 327	28, 975	9, 075	25, 448	104, 193
Total investment cost	185, 402	129, 995	123, 207	315, 230	75, 726	280, 004	1, 109, 564
Debit or credit to other divisions	....	+7, 800	−480	−7, 320	+18, 340	−18, 340	....
Total investment cost to division	185, 402	137, 795	122, 727	307, 910	94, 066	261, 664	1, 109, 564
Investment made as of midyear, 1919	82, 736	41, 263	33, 335	131, 655	23, 851	103, 506	416, 346
New money required	102, 666	96, 532	89, 392	176, 255	70, 215	158, 158	693, 218

[a] Includes a portion of the Pittston plant investment.

COST OF POWER.

Table 72 gives the annual production cost of the power plants for the superpower zone, Table 73 the annual transmission-system cost, and Table 74 the total cost of power delivered to load centers.

The costs given in Appendix B consider only production by the electric utilities and represent the cost of power at their bus bars. These costs, compared to the production cost of all the plants of the superpower system, are as follows:

TABLE 69.—*Production cost per kilowatt-hour net generated.*

	1919	1925	1930
Cost for electric utilities, 1919:			
Steam-electric	$0. 0212	$0. 0212	$0. 0212
Hydroelectric	. 0094	. 0094	. 0094
All plants	. 0193	. 0193	. 0193
Cost for superpower system:			
Steam-electric	. 0108	. 0107	. 0102
Hydroelectric	. 0061	. 0061	. 0058
All plants	. 0098	. 0098	. 0093
Reduction by superpower system	. 0095	. 0095	. 0100

To the production cost of the superpower system must be added the transmission cost to determine the cost of power delivered at the load centers.

The average unit cost of power delivered by the superpower system to the load centers is stated below.

TABLE 70.—*Unit cost of power delivered to load centers.*

	1919		1925		1930	
	Per kilowatt-hour.	Per kilowatt-year of demand.	Per kilowatt-hour.	Per kilowatt-year of demand.	Per kilowatt-hour.	Per kilowatt-year of demand.
Operating cost	$0.0045	$17.85	$0.0050	$20.40	$0.0046	$19.10
Fixed charges	.0064	25.40	.0058	24.00	.0056	23.10
General expense	.0004	1.55	.0004	1.60	.0004	1.60
	.0113	44.80	.0112	46.00	.0106	43.80

TABLE 71.—*Annual cost for power delivered to load centers by superpower system and cost for independent operation under conditions of 1919.*

	1919	1925	1930
Independent operation (power plants only):			
Fuel	$125,000,000	$151,000,000	$203,800,000
Maintenance, labor, and supplies	47,905,000	69,425,000	93,440,000
Fixed charges and general expense	190,300,000	227,150,000	305,900,000
	363,205,000	447,575,000	603,140,000
Superpower operation (power plants and transmission system):			
Fuel	61,815,000	87,216,000	108,094,000
Maintenance, labor, and supplies	24,829,000	27,451,000	33,905,000
Fixed charges and general expense	130,511,000	142,638,000	182,608,000
	217,155,000	257,305,000	324,607,000
Saving by superpower operation:			
Fuel	63,185,000	63,784,000	95,706,000
Maintenance, labor, and supplies	23,076,000	41,974,000	59,535,000
Fixed charges and general expenses	59,789,000	84,512,000	123,292,000
	146,050,000	190,270,000	278,533,000

The estimated fuel saving for 1925 is very little greater in dollars than that for 1919, owing to the lower unit coal cost per ton for superpower operation in the earlier year. The cost of power for independent operation is computed on the 1919 unit cost given in Appendix B. The value of fuel saving as here stated will therefore not check with the value given on page 163, where a definite cost per ton has been used in obtaining the result.

The total investment in electric-utility company plants in 1919, as shown by reproduction cost, was $598,277,000. Plants to the value of $416,346,000 are to be incorporated in the superpower system, leaving plants to be abandoned represented by a reproduction cost of $181,931,000.

The net saving effected by the superpower system is arrived at by deducting from the gross saving the cost of money, taxes, insurance, and sinking fund on these abandoned plants, the investment in which must be gradually amortized. The cost of money, insurance, and taxes on the abandoned plants will amount to $21,800,000 a year, and a sinking fund of $17,800,000 a year will amortize the investment in these plants in about eight years on a 7 per cent annuity basis. The deduction from the gross saving is therefore $39,600,000 a year, and the net savings are for 1919, $106,450,000; for 1925, $150,670,000; for 1930, $238,933,000.

If in 1930 the superpower zone were supplied with power from an interconnected system in which all the new power plants were of the steam-electric type and were located as close to the load centers as the available supply of condensing water would permit, the total investment in such a system would be $1,064,716,000, and the annual cost of power delivered to the load centers would be $348,084,000. The combination of base-load steam-electric plants located both at tidewater and in the anthracite mining region with hydroelectric plants increases the investment cost to $1,109,564,000 but reduces the annual cost of power delivered to the load centers to $278,534,000—a saving of $69,550,000 annually on an increased investment of $44,838,000.

By taking advantage of the partial regional diversity existing between the Anthracite division and the Southern and Metropolitan divisions and by producing large blocks of power in the Sunbury, Nescopeck, and Pittston base-load steam-electric plants in connection with the development of the Delaware River project to carry peak loads, as recommended for 1930, and by transmitting such of this power as is not absorbed by the Anthracite division to the Metropolitan and Southern divisions over the 220,000-volt transmission lines shown on Plates II and III, power could be delivered to these three divisions at the low average cost of 9.7 mills per kilowatt-hour. On the other hand, if the diversity existing between these divisions were ignored and the power were produced in steam-electric plants located as near the centers where it is used as the available supply of condensing water would permit, and if there were no transmission-line connection between the Anthracite and the Metropolitan and Southern divisions, the corresponding cost of power delivered to the load centers of these divisions would be 10.8 mills per kilowatt-hour.

As it will require about eight years to construct the proposed St. Lawrence hydroelectric works and about the same length of time to obtain additional capacity at Niagara Falls that could be released to the superpower zone, the load requirements of 1930 must be met by other facilities. However, if these developments were completed by 1930, the load growth in the Eastern New England, Western New England, and Mohawk-Hudson divisions should be sufficient to absorb the available output of the St. Lawrence by 1932, and that of the Metropolitan division should be sufficient to absorb 300,000 kilowatts at a load factor of 80 per cent from Niagara in the same year. It is believed from consultation with the best-informed authorities on these two projects that power could be purchased from them at not more than $20 per horsepower-year delivered at their bus bars, and accordingly this figure is used in determining their effect on the cost of power to those divisions of the superpower zone so supplied.

The estimated average cost for St. Lawrence power delivered in 1932 at Utica and Schenectady, N. Y., and Northampton, Mass., is 4.6 mills per kilowatt-hour for 600,000 kilowatts at a load factor of 80 per cent. The total annual cost for all power delivered in 1932 to the load centers of the Eastern New England, Western New England, and Mohawk-Hudson divisions with St. Lawrence power would be $130,273,000. Were the excess energy requirement of 1932 over that of 1930 furnished by new steam-electric plants, the total cost would be $141,601,000. The development of St. Lawrence River would therefore save $11,328,000 annually to these geographic divisions. The total investment required for equipment to use St. Lawrence purchased power would be $24,826,000 less than that required if new steam-electric plants were constructed to supply this excess energy. In the Eastern New England, Western New England, and Mohawk-Hudson divisions, which lie farthest from the coal fields, the cost of power generated by steam-electric plants is inherently high, and therefore the St. Lawrence development will be of very great benefit to these divisions.

The Metropolitan division by 1932 can absorb 300,000 kilowatts of Niagara power delivered at a load factor of 80 per cent. The cost of this power delivered at Paterson, N. J., will be about 5.7 mills per kilowatt-hour. The total cost to the Metropolitan division for the power it will require in 1932, if Niagara power is used, will be $107,651,000. If the growth in energy required between 1930 and 1932 were supplied from new steam-electric plants located in the Metropolitan division, the total cost for power to the division in that year would be $110,899,000, showing a saving of $3,248,000 in favor of Niagara power. Were the power purchased from the Niagara power interests, so that no investment by the superpower system in hydroelectric power plants at that location would be required, the total added investment for 1932 would be $5,080,000 less than that which would be required if the Niagara power were displaced by steam-electric power.

TABLE 72.—*Total annual production cost for superpower system for 1919, 1925, and 1930.*

Geographic division.	Annual operating cost.				Annual fixed charges.	Annual production cost.	
	Fuel.	Labor, maintenance, and supplies.	Total.	Per kilowatt-hour.		Total.	Per kilowatt-hour.
1919.							
Eastern New England:							
Steam-electric plants—							
Present	$4,132,000	$2,655,000	$6,787,000	$0.0131	$10,606,000	$17,393,000	$0.0336
New	8,620,000	1,490,000	10,110,000	.0043	6,580,000	16,690,000	.0070
	12,752,000	4,145,000	16,897,000	.0058	17,186,000	34,083,000	.0118
Hydroelectric plants—							
Present	....	388,000	388,000	.0014	2,394,000	2,782,000	.0104
New	....	....	....	....	....	....	....
	....	388,000	388,000	.0014	2,394,000	2,782,000	.0104
All plants	12,752,000	4,533,000	17,285,000	.0055	19,580,000	36,865,000	.0117
Western New England:							
Steam-electric plants—							
Present	851,000	942,000	1,793,000	.0233	3,928,000	5,721,000	.0743
New	4,130,000	996,000	5,126,000	.0047	4,785,000	9,911,000	.0091
	4,981,000	1,938,000	6,919,000	.0059	8,713,000	15,632,000	.0133
Hydroelectric plants—							
Present	....	438,000	438,000	.0013	2,477,000	2,915,000	.0086
New	....	100,000	100,000	.0004	1,156,000	1,2561000	.0055
	....	538,000	538,000	.0009	3,633,000	4,171,000	.0073
All plants	4,981,000	2,476,000	7,457,000	.0043	12,346,000	19,803,000	.0114
Mohawk-Hudson:							
Steam-electric plants—							
Present	272,000	212,000	484,000	.0242	1,153,000	1,637,000	.082
New	2,180,000	640,000	2,820,000	.0047	3,350,000	6,170,000	.0102
	2,452,000	852,000	3,304,000	.0053	4,503,000	7,807,000	.0125
Hydroelectric plants—							
Present	....	446,000	446,000	.0012	3,787,000	4,233,000	.0117
New	....	200,000	200,000	.0005	2,615,000	2,815,000	.0074
	....	646,000	646,000	.0008	6,402,000	7,048,000	.0095
All plants	2,452,000	1,498,000	3,950,000	.0029	10,905,000	14,855,000	.0109
Metropolitan:							
Steam-electric plants—							
Present	16,550,000	6,343,000	22,893,000	.0077	20,657,000	43,550,000	.0147
New	5,878,000	1,622,000	7,500,000	.0043	6,980,000	[a]14,480,000	.0083
	22,428,000	7,965,000	30,393,000	.0068	27,637,000	58,030,000	.0130
Hydroelectric plants—							
Present	....	67,000	67,000	.003	370,000	437,000	.0198
New	....	350,000	350,000	.0004	3,380,000	3,730,000	.0044
	....	417,000	417,000	.0005	3,750,000	4,167,000	.0048
All plants	22,428,000	8,382,000	30,810,000	.0057	31,387,000	62,197,000	.0115
Anthracite:							
Steam-electric plants—							
Present	2,752,000	1,007,000	3,758,000	.007	3,614,000	7,372,000	.0137
New	4,135,000	1,395,000	5,530,000	.0028	5,280,000	[a]10,810,000	.0055
	6,887,000	2,401,000	9,288,000	.0035	8,894,000	18,182,000	.0068

[a] Includes a portion of the annual production cost of the Pittston plant.

TABLE 72.—*Total annual production cost for superpower system for 1919, 1925, and 1930*—Continued.

Geographic division.	Annual operating cost.				Annual fixed charges.	Annual production cost.	
	Fuel.	Labor, maintenance, and supplies.	Total.	Per kilowatt-hour.		Total.	Per kilowatt-hour.
1919—Continued.							
Anthracite—Continued.							
Hydroelectric plants—							
Present	....	$64,000	$64,000	$0.004	$183,000	$247,000	$0.0155
New	....	....	....	....	....	....	....
	....	64,000	64,000	.004	183,000	247,000	.0155
All plants	$6,887,000	2,465,000	9,352,000	.0035	9,077,000	18,429,000	.0067
Southern:							
Steam-electric plants—							
Present	4,270,000	1,481,000	5,751,000	.0099	12,662,000	18,413,000	.0318
New	8,045,000	1,939,000	9,984,000	.0034	8,000,000	17,984,000	.0061
	12,315,000	3,420,000	15,735,000	.0045	20,662,000	36,397,000	.0140
Hydroelectric plants—							
Present	....	340,000	340,000	.0063	3,475,000	3,815,000	.007
New	....	395,000	395,000	.0003	4,280,000	4,675,000	.0033
	....	735,000	735,000	.0004	7,755,000	8,490,000	.0043
All plants	12,315,000	4,155,000	16,470,000	.0030	28,417,000	44,887,000	.0082
Superpower system:							
Steam-electric plants—							
Present	28,827,000	12,639,000	41,466,000	.0088	52,620,000	94,086,000	.0201
New	32,988,000	8,082,000	41,070,000	.0037	34,975,000	76,045,000	.0069
	61,815,000	20,721,000	82,536,000	.0053	87,595,000	170,131,000	.0108
Hydroelectric plants—							
Present	....	1,743,000	1,743,000	.0011	12,686,000	14,429,000	.0093
New	....	1,045,000	1,045,000	.0004	11,431,000	12,476,000	.0043
	....	2,788,000	2,788,000	.0006	24,117,000	26,905,000	.0061
All plants	61,815,000	23,509,000	85,324,000	.0042	111,712,000	197,036,000	.0098
1925.							
Eastern New England:							
Steam-electric plants—							
Present	4,928,000	2,655,000	7,583,000	.0147	10,606,000	18,189,000	.0352
New	12,435,000	1,830,000	14,265,000	.0051	8,120,000	22,385,000	.0080
	17,363,000	4,485,000	21,848,000	.0066	18,726,000	40,574,000	.0122
Hydroelectric plants—							
Present	....	388,000	388,000	.0014	2,394,000	2,782,000	.0104
New	....	....	....	....	....	....	....
	....	388,000	388,000	.0014	2,394,000	2,782,000	.0104
All plants	17,363,000	4,873,000	22,236,000	.0062	21,120,000	43,356,000	.0121
Western New England:							
Steam-electric plants—							
Present	1,029,000	942,000	1,971,000	.0256	3,928,000	5,899,000	.0767
New	5,600,000	1,100,000	6,700,000	.0055	5,293,000	11,993,000	.0098
	6,629,000	2,042,000	8,671,000	.0067	9,221,000	17,892,000	.0138

TABLE 72.—*Total annual production cost for superpower system for 1919, 1925, and 1930*—Continued.

Geographic division.	Annual operating cost.				Annual fixed charges.	Annual production cost.	
	Fuel.	Labor, maintenance, and supplies.	Total.	Per kilowatt-hour.		Total.	Per kilowatt-hour.
1925—Continued.							
Western New England—Con.							
Hydroelectric plants—							
Present	....	$438,000	$438,000	$0.0013	$2,477,000	$2,915,000	$0.0085
New	....	100,000	100,000	.0004	1,156,000	1,256,000	.0055
	....	538,000	538,000	.0009	3,633,000	4,171,000	.0073
All plants	$6,629,000	2,580,000	9,209,000	.0049	12,854,000	22,063,000	.0118
Mohawk-Hudson:							
Steam-electric plants—							
Present	324,000	212,000	536,000	.0268	1,153,000	1,689,000	.0844
New	4,380,000	890,000	5,270,000	.0051	4,296,000	9,566,000	.0092
	4,704,000	1,102,000	5,806,000	.0055	5,449,000	11,255,000	.0106
Hydroelectric plants—							
Present	....	446,000	446,000	.0012	3,787,000	4,233,000	.0117
New	....	200,000	200,000	.0005	2,615,000	2,815,000	.0074
	....	646,000	646,000	.0009	6,402,000	7,048,000	.0095
All plants	4,704,000	1,748,000	6,452,000	.0036	11,851,000	18,303,000	.0102
Metropolitan:							
Steam-electric plants—							
Present	19,800,000	6,343,000	26,143,000	.0088	20,657,000	46,800,000	.0158
New	12,190,000	2,419,000	14,609,000	.0048	10,030,000	[a] 24,639,000	.077
	31,990,000	8,762,000	40,752,000	.0071	30,687,000	71,439,000	.0123
Hydroelectric plants—							
Present	....	67,000	67,000	.0030	370,000	437,000	.0198
New	....	350,000	350,000	.0004	3,380,000	3,730,000	.0044
	....	417,000	417,000	.0005	3,750,000	4,167,000	.0048
All plants	31,990,000	9,179,000	41,169,000	.0061	34,437,000	75,606,000	.0112
Anthracite:							
Steam-electric plants—							
Present	3,046,000	1,006,000	4,052,000	.0075	3,614,000	7,666,000	.0143
New	4,025,000	1,256,000	5,281,000	.0031	4,710,000	[a] 9,991,000	.0058
	7,071,000	2,262,000	9,333,000	.0037	8,324,000	17,657,000	.0071
Hydroelectric plants—							
Present	....	64,000	64,000	.0040	183,000	247,000	.0155
New	....	....	....	....	....	....	....
	....	64,000	64,000	.0040	183,000	247,000	.0155
All plants	7,071,000	2,326,000	9,397,000	.0038	8,507,000	17,904,000	.0071
Southern:							
Steam-electric plants—							
Present	4,979,000	1,481,000	6,460,000	.0112	12,662,000	19,122,000	.0331
New	14,480,000	2,960,000	17,440,000	.0040	12,175,000	29,615,000	.0068
	19,459,000	4,441,000	23,900,000	.0048	24,837,000	48,737,000	.0099
Hydroelectric plants—							
Present	....	340,000	340,000	.0063	3,475,000	3,815,000	.007
New	....	395,000	395,000	.0003	4,280,000	4,675,000	.0033
	....	735,000	735,000	.0004	7,755,000	8,490,000	.0043
All plants	19,459,000	5,176,000	24,635,000	.0035	32,592,000	57,227,000	.0083

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[a] Includes a portion of the annual production cost of the Pittston plant.

TABLE 72.—*Total annual production cost for superpower system for 1919, 1925, and 1930*—Continued.

Geographic division.	Annual operating cost.				Annual fixed charges.	Annual production cost.	
	Fuel.	Labor, maintenance, and supplies.	Total.	Per kilowatt-hour.		Total.	Per kilowatt-hour.
1925—Continued.							
Superpower system:							
Steam-electric plants—							
Present	$34,106,000	$12,639,000	$46,745,000	$0.0100	$52,620,000	$99,365,000	$0.0212
New	53,110,000	10,455,000	63,565,000	.0043	44,624,000	108,189,000	.0074
	87,216,000	23,094,000	110,310,000	.0057	97,244,000	207,554,000	.0107
Hydroelectric plants—							
Present	....	1,743,000	1,743,000	.0011	12,686,000	14,429,000	.0093
New	....	1,045,000	1,045,000	.0004	11,431,000	12,476,000	.0043
	....	2,788,000	2,788,000	.0006	24,117,000	26,905,000	.0061
All plants	87,216,000	25,882,000	113,098,000	.0048	121,361,000	234,459,000	.0098
1930.							
Eastern New England:							
Steam-electric plants—							
Present	4,995,000	2,852,000	7,847,000	.0148	10,606,000	18,453,000	.0350
New	18,610,000	3,063,900	21,675,000	.0052	14,685,000	36,360,000	.0088
	23,605,000	5,917,000	29,522,000	.0063	25,291,000	54,813,000	.0117
Hydroelectric plants—							
Present	....	388,000	388,000	.0014	2,394,000	2,782,000	.0104
New	....	....	....	....	....	....	....
	....	388,000	388,000	.0014	2,394,000	2,782,000	.0104
All plants	23,605,000	6,305,000	29,910,000	.0061	27,685,000	57,595,000	.0116
Western New England:							
Steam-electric plants—							
Present	1,029,000	942,000	1,971,000	.0256	3,928,000	5,899,000	.0767
New	5,810,000	1,370,000	7,180,000	.0058	6,775,000	13,955,000	.0113
	6,839,000	2,312,000	9,151,000	.0070	10,703,000	19,854,000	.0151
Hydroelectric plants—							
Present	....	438,000	438,000	.0013	2,477,000	2,915,000	.0086
New	....	330,000	330,000	.0004	3,800,000	4,130,000	.0054
	....	768,000	768,000	.0007	6,277,000	7,045,000	.0064
All plants	6,839,000	3,080,000	9,919,000	.0041	16,980,000	26,899,000	.0112
Mohawk-Hudson:							
Steam-electric plants—							
Present	324,000	212,000	536,000	.0268	1,153,000	1,689,000	.0844
New	5,620,000	1,300,000	6,920,000	.0053	6,270,000	13,190,000	.0100
	5,944,000	1,512,000	7,456,000	.0056	7,423,000	14,879,000	.0112
Hydroelectric plants—							
Present	....	446,000	446,000	.0013	3,787,000	4,233,000	.0124
New	....	300,000	300,000	.0003	4,950,000	5,250,000	.0058
	....	746,000	746,000	.0006	8,737,000	9,483,000	.0077
All plants	5,944,000	2,258,000	8,202,000	.0032	16,160,000	24,362,000	.0095

TABLE 72.—*Total annual production cost for superpower system for 1919, 1925, and 1930*—Continued.

Geographic division.	Annual operating cost.				Annual fixed charges.	Annual production cost.	
	Fuel.	Labor, maintenance, and supplies.	Total.	Per kilowatt-hour.		Total.	Per kilowatt-hour.
1930—Continued.							
Metropolitan:							
Steam-electric plants—							
Present	$15,763,000	$5,992,000	$21,755,000	$0.0096	$20,657,000	$42,412,000	$0.0186
New	21,300,000	3,955,000	25,255,000	.0047	16,485,000	[a] 41,740,000	.0076
	37,063,000	9,947,000	47,010,000	.0064	37,142,000	84,152,000	.0103
Hydroelectric plants—							
Present	....	67,000	67,000	.003	370,000	437,000	.0198
New	....	650,000	650,000	.0005	6,800,000	7,450,000	.0060
	....	717,000	717,000	.0005	7,170,000	7,887,000	.0062
All plants	37,063,000	10,664,000	47,727,000	.0055	44,312,000	92,039,000	.0094
Anthracite:							
Steam-electric plants—							
Present	3,046,000	1,006,000	4,052,000	.0075	3,614,000	7,666,000	.0143
New	5,948,000	1,892,000	7,840,000	.0031	6,855,000	[a] 14,695,000	.0057
	8,994,000	2,898,000	11,892,000	.0036	10,469,000	22,361,000	.0067
Hydroelectric plants—							
Present	....	64,000	64,000	.004	183,000	247,000	.0155
New	....	....	....	....	....	....	....
	....	64,000	64,000	.004	183,000	247,000	.0155
All plants	8,994,000	2,962,000	11,956,000	.0036	10,652,000	22.608.000	.0067
Southern:							
Steam-electric plants—							
Present	4,979,000	1,481,000	6,460,000	.0112	12,662,000	19,122,000	.0331
New	20,670,000	4,310,000	24,980,000	.0040	17,765,000	42,745,000	.0069
	25,649,000	5,791,000	31,440,000	.0046	30,427,000	61,867,000	.0091
Hydroelectric plants—							
Present	....	340,000	340,000	.0006	3,475,000	3,815,000	.0070
New	....	625,000	625,000	.0003	6,526,000	7,151,000	.0033
	....	965,000	965.000	.0004	10,001,000	10,966,000	.0040
All plants	25,649,000	6,756,000	32,405,000	.0034	40,428,000	72,833,000	.0077
Superpower system:							
Steam-electric plants—							
Present	30,136,000	12,485,000	42,621,000	.0106	52,620,000	95,241,000	.0238
New	77,958,000	15,892,000	93,850,000	.0044	68,835,000	162,685,000	.0076
	108,094,000	28,377,000	136,471,000	.0054	121.455,000	257,926,000	.0102
Hydroelectric plants—							
Present	....	1,743,000	1,743,000	.0011	12,686,000	14,429,000	.0094
New	....	1,905,000	1,905.000	.0004	22,076,000	23,981,000	.0047
	....	3,648,000	3,648.000	.0006	34,762,000	38,410,000	.0058
All plants	108,094.000	32.028,000	140,119,000	.0044	156,217,000	296,336,000	.0093

[a] Includes a portion of the annual production cost of the Pittston plant.

TABLE 73.—*Annual cost of transmission system for superpower system, 1919, 1925, and 1930.*

Geographic division.	Operating.	Fixed charges.	Total.
1919.			
Eastern New England:			
Transmission lines	$37,000	$578,000	$615,000
Substations	123,000	584,000	707,000
	160,000	1,162,000	1,322,000
Western New England:			
Transmission lines	50,000	887,000	937,000
Substations	51,000	304,000	355,000
	101,000	1,191,000	1,292,000
Mohawk-Hudson:			
Transmission lines	48,000	855,000	903,000
Substations	87,000	504,000	591,000
	135,000	1,359,000	1,494,000
Metropolitan:			
Transmission lines	75,000	1,870,000	1,945,000
Substations	284,000	1,760,000	2,044,000
	359,000	3,630,000	3,989,000
Anthracite:			
Transmission lines	49,000	508,000	557,000
Substations	114,000	520,000	634,000
	163,000	1,028,000	1,191,000
Southern:			
Transmission lines	221,000	2,100,000	2,321,000
Substations	181,000	987,000	1,168,000
	402,000	3,087,000	3,489,000
Superpower system:			
Transmission lines	480,000	6,798,000	7,278,000
Substations	840,000	4,659,000	5,499,000
	1,320,000	11,457,000	12,777,000
1925.			
Eastern New England:			
Transmission lines	48,000	725,000	773,000
Substations	186,000	816,000	1,002,000
	234,000	1,541,000	1,775,000
Western New England:			
Transmission lines	49,000	888,000	937,000
Substations	133,000	585,000	718,000
	182,000	1,473,000	1,655,000
Mohawk-Hudson:			
Transmission lines	48,000	855,000	903,000
Substations	104,000	516,000	620,000
	152,000	1,371,000	1,523,000
Metropolitan:			
Transmission lines	75,000	1,870,000	1,945,000
Substations	347,000	1,990,000	2,337,000
	422,000	3,860,000	4,282,000
Anthracite:			
Transmission lines	19,000	573,000	592,000
Substations	150,000	665,000	815,000
	169,000	1,238,000	1,407,000

TABLE 73.—*Annual cost of transmission system for superpower system, 1919, 1925, and 1930*—Continued.

Geographic division.	Operating.	Fixed charges.	Total.
1925—Continued.			
Southern:			
Transmission lines	$221,000	$2,100,000	$2,321,000
Substations	189,000	1,242,000	1,431,000
	410,000	3,342,000	3,752,000
Superpower system:			
Transmission lines	460,000	7,011,000	7,471,000
Substations	1,109,000	5,814,000	6,923,000
	1,569,000	12,825,000	14,394,000
1930.			
Eastern New England:			
Transmission lines	48,000	725,000	773,000
Substations	194,000	915,000	1,109,000
	242,000	1,640,000	1,882,000
Western New England:			
Transmission lines	78,000	1,660,000	1,738,000
Substations	173,000	896,000	1,069,000
	251,000	2,556,000	2,807,000
Mohawk-Hudson:			
Transmission lines	132,000	1,110,000	1,242,000
Substations	130,000	700,000	830,000
	262,000	1,810,000	2,072,000
Metropolitan:			
Transmission lines	80,000	2,010,000	2,090,000
Substations	426,000	2,335,000	2,761,000
	506,000	4,345,000	4,851,000
Anthracite:			
Transmission lines	24,000	603,000	627,000
Substations	174,000	762,000	936,000
	198,000	1,365,000	1,563,000
Southern:			
Transmission lines	167,000	2,300,000	2,467,000
Substations	253,000	1,440,000	1,693,000
	420,000	3,740,000	4,160,000
Superpower zone:			
Transmission lines	529,000	8,408,000	8,937,000
Substations	1,348,000	7,050,000	8,398,000
	1,877,000	15,458,000	17,335,000

TABLE 74.—*Annual cost of delivered power for the superpower system, 1919, 1925, and 1930.*

Geographic division.	Operating cost.		Fixed charges.	General expense.	Cost of delivered power.	
	Total.	Per kilowatt-hour.			Total.	Per kilowatt-hour.
1919.						
Eastern New England:						
Cost of power produced	$17,445,000	....	$20,742,000	$1,333,000	$39,520,000	....
Debit or credit to other divisions	0	....	0	0	0	....
Net cost	17,445,000	$0.0058	20,742,000	1,333,000	39,520,000	$0.0131
Western New England:						
Cost of power produced	7,558,000	....	13,537,000	740,000	21,835,000	....
Debit or credit to other divisions	0	....	0	0	0	....
Net cost	7,558,000	.0045	13,537,000	740,000	21,835,000	.0131
Mohawk-Hudson:						
Cost of power produced	4,085,000	....	12,264,000	572,000	16,921,000	....
Debit or credit to other divisions	+540,000	....	+560,000	+60,000	+1,160,000	....
Net cost	4,625,000	.0035	12,824,000	632,000	18,081,000	.0137
Metropolitan:						
Cost of power produced	31,169,000	....	35,017,000	2,320,000	68,506,000	....
Debit or credit to other divisions	−540,000	....	−560,000	−60,000	−1,160,000	....
Net cost	30,629,000	.0055	34,457,000	2,260,000	67,346,000	.0120
Anthracite:						
Cost of power produced	9,515,000	....	10,105,000	687,000	20,307,000	....
Debit or credit to other divisions	+3,000,000	....	+3,200,000	+470,000	+6,670,000	....
Net cost	12,515,000	.0042	13,305,000	1,157,000	26,977,000	.0090
Southern:						
Cost of power produced	16,872,000	....	31,504,000	1,690,000	50,066,000	....
Debit or credit to other divisions	−3,000,000	....	−3,200,000	−470,000	−6,670,000	....
Net cost	13,872,000	.0029	28,304,000	1,220,000	43,396,000	.0093
Superpower system	86,644,000	.0045	123,169,000	7,342,000	217,155,000	.0113
1925.						
Eastern New England:						
Cost of power produced	22,470,000	....	22,661,000	1,580,000	46,711,000	....
Debit or credit to other divisions	0	....	0	0	0	....
Net cost	22,470,000	.0065	22,661,000	1,580,000	46,711,000	.0135
Western New England:						
Cost of power produced	9,391,000	....	14,327,000	830,000	24,548,000	....
Debit or credit to other divisions	+680,000	....	+710,000	+25,000	+1,415,000	....
Net cost	10,071,000	.0053	15,037,000	855,000	25,963,000	.0136
Mohawk-Hudson:						
Cost of power produced	6,604,000	....	12,957,000	685,000	20,246,000	....
Debit or credit to other divisions	+190,000	....	+210,000	+15,000	+415,000	....
Net cost	6,794,000	.0038	13,167,000	700,000	20,661,000	.0117
Metropolitan:						
Cost of power produced	41,591,000	....	38,297,000	2,800,000	82,688,000	....
Debit or credit to other divisions	−870,000	....	−910,000	−40,000	−1,820,000	....
Net cost	40,721,000	.0059	37,387,000	2,760,000	80,868,000	.0117
Anthracite:						
Cost of power produced	9,566,000	....	9,745,000	677,000	19,988,000	....
Debit or credit to other divisions	+960,000	....	+980,000	+165,000	+2,105,000	....
Net cost	10,526,000	.0040	10,725,000	842,000	22,093,000	.0085

TABLE 74.—*Annual cost of delivered power for the superpower system, 1919, 1925, and 1930*—Continued.

Geographic division.	Operating cost.		Fixed charges.	General expense.	Cost of delivered power.	
	Total.	Per kilowatt-hour.			Total.	Per kilowatt-hour.
1925—Continued.						
Southern:						
Cost of power produced	$25,045,000	....	$35,934,000	$2,135,000	$63,114,000	....
Debit or credit to other divisions	−960,000	....	−980,000	−165,000	−2,105,000	....
Net cost	24,085,000	$0.0038	34,954,000	1,970,000	61,009,000	$0.0098
Superpower system	114,667,000	.0050	133,931,000	8,707,000	257,305,000	.0112
1930.						
Eastern New England:						
Cost of power produced	30,152,000	....	29,325,000	2,081,000	61,558,000	....
Debit or credit to other divisions	0	....	0	0	0	....
Net cost	30,152,000	.0063	29,325,000	2,081,000	61,558,000	.0129
Western New England:						
Cost of power produced	10,170,000	....	19,536,000	1,038,000	30,744,000	....
Debit or credit to other divisions	+863,000	....	+870,000	+62,000	+1,795,000	....
Net cost	11,033,000	.0045	20,406,000	1,100,000	32,539,000	.0131
Mohawk-Hudson:						
Cost of power produced	8,464,000	....	17,970,000	890,000	27,324,000	....
Debit or credit to other divisions	+257,000	....	+260,000	+18,000	+535,000	....
Net cost	8,721,000	.0035	18,230,000	908,000	27,859,000	.0110
Metropolitan:						
Cost of power produced	48,233,000	....	48,657,000	3,390,000	100,280,000	....
Debit or credit to other divisions	−1,120,000	....	−1,130,000	−80,000	−2,330,000	....
Net cost	47,113,000	.0054	47,527,000	3,310,000	97,950,000	.0111
Anthracite:						
Cost of power produced	12,154,000	....	12,017,000	846,000	25,017,000	....
Debit or credit to other divisions	+2,160,000	....	+2,950,000	+120,000	+5,230,000	....
Net cost	14,314,000	.0040	14,967,000	966,000	30,247,000	.0084
Southern:						
Cost of power produced	32,825,000	....	44,168,000	2,690,000	79,683,000	....
Debit or credit to other divisions	−2,160,000	....	−2,950,000	−120,000	−5,230,000	....
Net cost	30,665,000	.0036	41,218,000	2,570,000	74,453,000	.0087
Superpower system	141,998,000	.0046	171,673,000	10,935,000	324,606,000	.0106

COST OF POWER DELIVERED TO THE LOAD CENTERS FROM THE NEW POWER PLANTS AND THE TRANSMISSION SYSTEM OF THE SUPERPOWER SYSTEM.

The superpower system as analyzed in the preceding sections comprises two distinct elements—(1) the present power plants incorporated into the system and (2) the new power plants and the transmission system. The amount of new power-plant capacity required is as follows:

TABLE 75.—*New power-plant capacity for superpower system, in kilowatts.*

Geographic division.	1919	1925	1930
Eastern New England	350,000	450,000	810,000
Western New England	320,000	350,000	555,000
Mohawk-Hudson	280,000	340,000	510,000
Metropolitan	423,000	573,000	1,100,000
Anthracite	450,000	450,000	600,000
Southern	695,000	935,000	1,405,000
Superpower zone	2,528,000	3,098,000	4,980,000

The investment cost for the new facilities given in Table 76 is 52.2 per cent of the total investment cost for the superpower system in 1925 and 62.5 per cent of the total in 1930.

The cost of power delivered to the load centers from the new facilities of the superpower system is shown by Table 77 to be 54.3 per cent of the total cost for the superpower system in 1925 and 65 per cent of the total in 1930.

The present power plants proposed for incorporation in the superpower system will be a very important factor in the earlier stages of its being. Although theoretically power could be generated more cheaply and a greater amount of coal could be conserved by abandoning practically every steam-electric power plant now located within the zone, this procedure is not desirable, practicable, or financially possible.

If the power plants retained are operated by the utilities as set forth on pages 157–161, the average cost of power purchased from the new facilities of the superpower system would be $0.0084 per kilowatt-hour measured at the receiving busses of the electric utilities at the load centers. To obtain this result, however, it is essential that all power plants within the zone be so operated that the resulting cost to all concerned will be the lowest. This end can be accomplished only by the operation of the older, less efficient plants for peak load and by the operation of the new, highly efficient plants for base load at high capacity factors.

TABLE 76.—*Investment cost for new power plants and transmission system of the superpower system, 1919, 1925, and 1930, in thousands of dollars.*

	Eastern New England.	Western New England.	Mohawk-Hudson.	Metropolitan.	Anthracite.	Southern.	Superpower zone.
1919.							
New plants	41,100	38,890	41,044	[a] 69,270	[a] 33,000	83,035	306,339
Transmission system	7,787	8,245	9,257	24,300	6,888	21,192	77,669
	48,887	47,135	50,301	93,570	39,888	104,227	384,008
Debit or credit to other divisions	....	....	−3,800	+3,800	+2,655	−2,655	....
Net investment	48,887	47,135	46,501	97,370	42,543	101,572	384,008
1925.							
New plants	50,700	42,100	46,974	[a] 88,400	[a] 29,420	109,120	366,714
Transmission system	10,288	10,001	9,334	25,781	8,248	22,777	86,429
	60,988	52,101	56,308	114,181	37,668	131,897	453,143
Debit or credit to other divisions	....	+5,980	−780	−5,200	+1,435	−1,435	....
Net investment	60,988	58,081	55,528	108,981	39,103	130,462	453,143
1930.							
New plants	91,750	71,280	77,545	[a] 154,600	[a] 42,800	151,050	589,025
Transmission system	10,916	17,452	12,327	28,975	9,075	25,448	104,193
	102,666	88,732	89,872	183,575	51,875	176,498	693,218
Debit or credit to other divisions	....	+7,800	−480	−7,320	+18,340	−18,340	....
Net investment	102,666	96,532	89,392	176,255	70,215	158,158	693,218

[a] Includes a part of the investment in the Pittston plant.

TABLE 77.—*Cost of power delivered from new power plants and transmission system of superpower system for 1919, 1925, and 1930.*

	Eastern New England.	Western New England.	Mohawk-Hudson.	Metropolitan.	Anthracite.	Southern.	Superpower zone.
1919.							
Power (millions of kilowatt-hours):							
Delivered to division	3,016	1,671	1,313	5,590	3,005	4,669	19,264
Generated by old plants	785	417	381	2,982	553	1,121	6,239
Delivered from new facilities	2,231	1,254	932	2,608	2,452	3,548	13,025
Annual cost (thousands of dollars):							
Production cost, new plants	16,690	11,167	8,985	[a] 18,210	[a] 10,810	22,659	88,521
Transmission cost	1,322	1,292	1,494	3,989	1,191	3,489	12,777
General expense	630	438	358	782	420	915	3,543
	18,642	12,897	10,837	22,981	12,421	27,063	104,841
Debit or credit to other divisions	....	....	+1,160	−1,160	+6,670	−6,670	....
Total cost of power delivered from new facilities	18,642	12,897	11,997	21,821	19,091	20,393	104,841
Cost per kilowatt-hour	$0.0084	$0.0103	$0.0129	$0.0084	$0.0078	$0.0057	$0.0080
1925.							
Power (millions of kilowatt-hours):							
Delivered to division	3,458	1,909	1,767	6,903	2,600	6,233	22,870
Generated by old plants	785	417	381	2,982	553	1,121	6,239
Delivered from new facilities	2,673	1,492	1,386	3,921	2,047	5,112	16,631
Annual cost (thousands of dollars):							
Production cost, new plants	22,385	13,249	12,381	[a] 28,369	[a] 9,991	34,290	120,665
Transmission cost	1,775	1,655	1,523	4,282	1,407	3,752	14,394
General expense	845	522	487	1,140	398	1,330	4,722
	25,005	15,426	14,391	33,791	11,796	39,372	139,781
Debit or credit to other divisions	....	+1,405	+415	−1,820	+2,105	−2,105	....
Total cost of power delivered from new facilities	25,005	16,831	14,806	31,971	13,901	37,267	139,781
Cost per kilowatt-hour	$0.0093	$0.0113	$0.0107	$0.0082	$0.0068	$0.0073	$0.0084
1930.							
Power (millions of kilowatt-hours):							
Delivered to division	4,755	2,477	2,526	8,781	3,606	3,567	30,712
Generated by old plants	797	417	361	2,296	553	1,121	5,547
Delivered from new facilities	3,958	2,060	2,165	6,485	3,053	7,446	25,165
Annual cost (thousands of dollars):							
Production cost, new plants	36,360	18,085	18,440	[a] 49,190	[a] 14,695	49,896	186,666
Transmission cost	1,882	2,807	2,072	4,851	1,563	4,160	17,335
General expense	1,330	795	735	1,835	755	1,700	7,150
	39,572	21,687	21,247	55,876	17,013	55,756	211,151
Debit or credit to other divisions	....	+1,795	+535	−2,330	+5,230	−5,230	....
Total cost of power delivered from new facilities	39,572	23,482	21,782	53,546	22,243	50,526	211,151
Cost per kilowatt-hour	$0.0100	$0.0114	$0.0101	$0.0083	$0.0073	$0.0068	$0.0084

[a] Includes a part of the annual production cost of the Pittston plant.

APPENDIX F.

STEAM-ELECTRIC PLANTS FOR THE SUPERPOWER SYSTEM.

By HENRY FLOOD, jr., and others of the engineering staff.

EXISTING PLANTS TO BE RETAINED.

CAPACITY AND PERFORMANCE.

The principal factor in determining whether or not a given plant shall be incorporated in the superpower system is fuel performance. Other factors, however, are strategic location for regulation of voltage and the adaptability of the plant to expansion. The total effective capacity to be retained, as shown by Table 78, is 79 per cent of the total effective capacity of the steam-electric plants on December 31, 1919.

TABLE 78.—*Capacity and performance in 1919 of steam-electric plants to be retained in the superpower system.*

Division.	Effective capacity (kilowatts).	Output (millions of kilowatt-hours).	Fuel used (thousands of short tons).	Effective capacity factor (per cent).	Coal used per kilowatt-year of effective capacity (short tons).
Bituminous coal plants:					
Eastern New England	514, 580	1, 290. 4	1, 318. 5	28. 6	2. 56
Western New England	171, 800	294. 4	330. 8	19. 5	1. 93
Mohawk	31, 750	21. 1	52. 0	7. 6	1. 64
Hudson	14, 000	33. 1	45. 5	26. 8	3. 25
Metropolitan	1, 130, 500	3, 474. 1	3, 734. 0	35. 0	3. 30
Anthracite	48, 000	164. 3	234. 9	39. 2	4. 90
Southern	632, 800	2, 141. 3	1, 887. 9	38. 6	2. 98
	2, 543, 430	7, 418. 7	7, 603. 6	33. 2	2. 90
Anthracite plants:					
Anthracite	111, 500	480. 2	979. 5	29. 1	8. 78
Southern	21, 700	22. 0	44. 3	11. 5	2. 04
	133, 200	502. 2	1, 023. 8	42. 8	7. 68
Grand total	2, 676, 630	7, 920. 9	8, 627. 4	33. 8	3. 23

Figure 26 shows the estimated average fuel performance during 1919 of plants using anthracite and bituminous coal. The plants to be retained that burn bituminous coal are those that use not over 50 per cent more than the plants of type B–3 (see p. 185) and those to be retained that burn anthracite are those that use not over 125 per cent more coal than the plants of type A–3 (see p. 185).

ESTIMATED INVESTMENT COST.

In 1919 there were in operation in the superpower zone 400 steam-electric public-utility plants. Most of these plants were built so long ago that their cost can not readily be estimated. A knowledge of the investment made in existing plants is required for the purpose of computing the fixed charges and the total cost of energy. In comparing the total cost of power produced under a superpower system with the cost of that produced under independent operation the investment cost for each element of both systems must be computed in the same manner.

Figure 27 shows the estimated unit investment cost required for effective plant capacity and for excess generator capacity. Many of the existing plants have insufficient boiler capacity for the entire prime-mover installation, so that it is necessary to estimate the cost of excess generator capacity. These estimates are the result of an examination in detail of the items of cost of plants having capacities between 500 and 175,000 kilowatts. To insure the use of fair cost values authorities on this subject have been consulted freely.

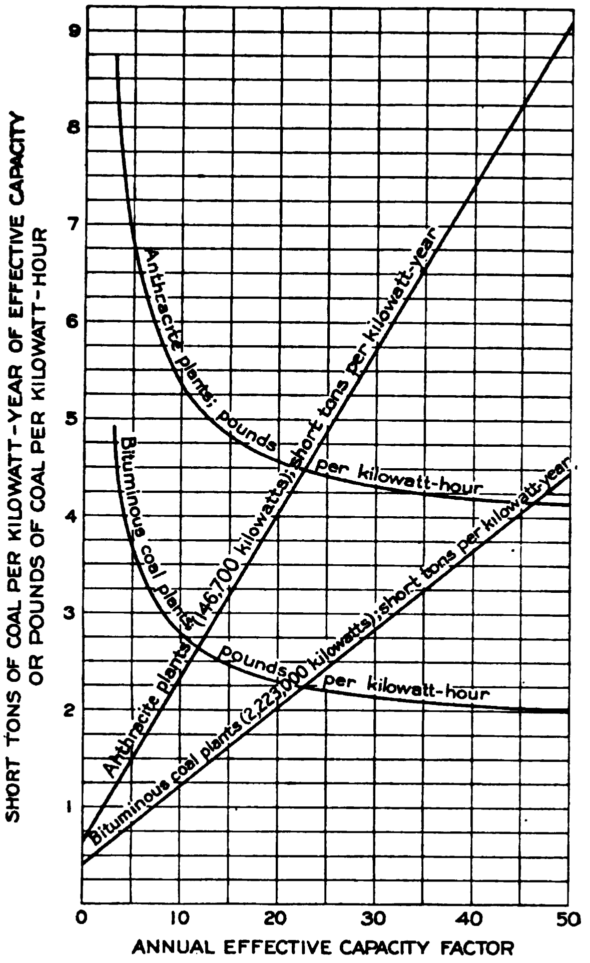


FIGURE 26.—Average performance of existing steam-electric plants to be retained in the superpower system.

The estimated cost of constructing, in midyear of 1919, the steam-electric plants to be retained in the superpower system is as follows:

Eastern New England	$66, 235, 000
Western New England	24, 550, 000
Mohawk	5, 030, 000
Hudson	2, 170, 000
Metropolitan	129, 105, 000
Anthracite	22, 586, 000
Southern	79, 543, 000
Superpower zone	329, 219, 000

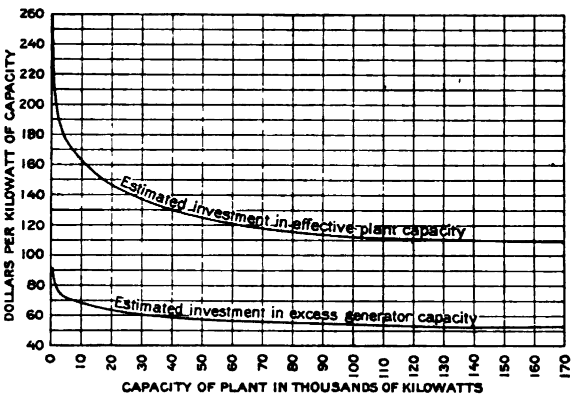


FIGURE 27.—Estimated unit investment for existing steam-electric plants as if constructed in midyear of 1919.

ESTIMATED ANNUAL PRODUCTION COST.

The fixed charges for the plants to be retained, computed at 16 per cent of the investment cost given above, are stated below. (See also Appendix L.) The cost in 1919 for maintenance, labor, and supplies has been used, and the cost of coal as given in Appendix J.

Eastern New England	$10, 606, 000
Western New England	3, 928, 000
Mohawk	805, 000
Hudson	348, 000
Metropolitan	20, 657, 000
Anthracite	$3, 614, 000
Southern	12, 662, 000
Superpower zone	52, 620, 000

Figures 28 and 29 give the average production cost of all existing steam-electric plants to be retained in the superpower system, and in Table 79 the operating cost, fixed charges, and total production costs of these plants are compared to the estimated annual cost of base-load steam-electric plants.

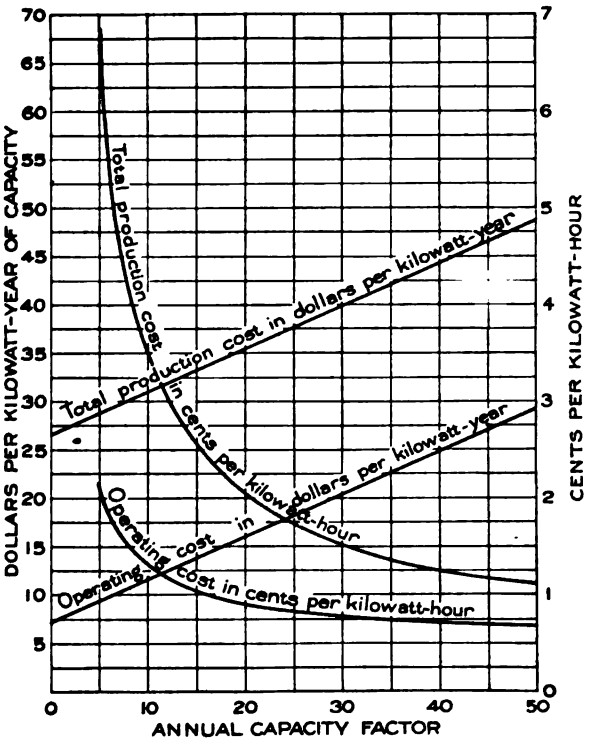


FIGURE 28.—Estimated average production and operating costs for existing steam-electric plants burning bituminous coal to be retained in superpower system. Coal figured at $5.30 per short ton in bunkers.

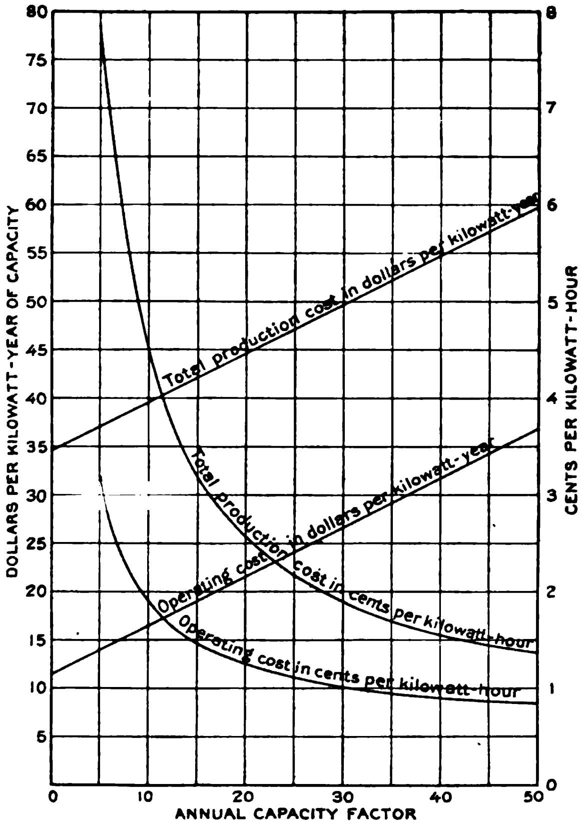


FIGURE 29.—Estimated average cost of production and operation for existing steam-electric plants burning anthracite to be retained in superpower system. Coal figured at $3 per long ton.

TABLE 79.—*Costs for new and retained steam plants, at an annual capacity factor of 30 per cent, in cents per kilowatt-hour.*

	Operating cost.	Fixed charges.	Total production cost.
Plants burning bituminous coal:			
Existing plants retained	0.77	0.73	1.50
Base-load plants	.49	.59	1.08
Difference	.28	.14	.42
Plants burning anthracite:			
Existing plants retained	1.00	.87	1.87
Base-load plants	.42	.65	1.07
Difference	.58	.22	.80

NEW BASE-LOAD PLANTS.

LOCATION, CHARACTER, SIZE, AND DESIGN.

The location of the new base-load steam-electric plants will be determined largely by the availability of condensing water and the convenience and cost of coal delivery and storage.

Except as qualified by character of load and relation to existing hydroelectric and steam-electric plants, the new plants will be operated at high annual capacity factors. To provide flexibility in design and cost the plants will be constructed in multiples of 30,000 kilowatts and may therefore use single-cylinder turbines of 30,000 kilowatts or multiple-cylinder turbines of 60,000 kilowatts.

The maximum size of steam-electric station has been fixed at 360,000 kilowatts. This limit has been determined by considering on the one hand the ability to transmit energy away from the plant and on the other the hazard incident to the possibility of destruction through unusual catastrophe.

It is desirable to standardize as far as may be possible all the units or elements that enter into the construction of a plant, such as boiler equipment, turbines, transformers, and switch gear, in order to reduce the cost of maintenance, to obviate the need of carrying many small parts, and thus, by making quick repairs possible, to insure continuity of service.

After consultation with many representatives of manufacturers of equipment and with designing and operating engineers, the following basic operating requirements for base-load steam-electric plants have been selected:

Steam pressure at turbine throttle, 300 pounds per square inch.
Superheat at turbine throttle, 230° F.
Final temperature at turbine throttle, 652° F.
Absolute pressure at turbine exhaust nozzle, 1 inch of mercury.

These requirements have been thoroughly tried, and conformity with them should assure reliability of service.

Base-load steam-electric plants are of two general types—type A, using anthracite, and type B, using bituminous coal. The two types in turn have been subdivided into three classes—class 1, stokers, boilers, economizers, and air preheaters; class 2, stokers, boilers, and economizers; class 3, stokers and 20-tube high boilers. The stokers for type A are chain grate; those for type B are underfeed. The relative performance of these types, the relative investments, and the relative production costs are discussed in the following sections of this appendix.

The load to be carried on these plants will not include sudden peaks of short duration. Such peaks as they will have to carry will be of long duration. Accordingly, a liberal boiler capacity has been planned for the turbines, ranging from about 4 kilowatts per boiler-horsepower for a plant of class 3 to about 4.65 kilowatts for a plant of class 1. The boiler plant can thus operate at a very high efficiency over the entire range of load. Plants of class 1 can carry about 175 per cent of their rating at normal loads and 215 per cent on sustained peaks; plants of class 3 can carry about 160 per cent on normal loads and 190 per cent on sustained peaks. The boiler and stoker arrangement is so planned, however, that 300 per cent rating can readily be obtained if necessary for peaks of short duration. Large combustion chambers are used, 3½ cubic feet per boiler-horsepower having been allowed.

Should the burning of pulverized or process fuels become profitable in conjunction with the production of power, it will be possible to install the necessary apparatus with little expense, as this contingency has been considered in designing the boiler plant.

With 30,000-kilowatt turbines surface condensers having approximately 50,000 square feet of surface will be used. This amount of surface may be varied at different localities because of local water conditions. Under average conditions of obtaining condensing water for the entire zone this amount of condenser capacity will be ample.

Base-load stations will be located outside of congested centers of population.

ESTIMATED PERFORMANCE.

The estimated performance for base-load steam-electric plants is shown in Plate VIII for plants of types A–3, B–1, B–2, and B–3.

It is not considered advisable to use pressures or temperatures higher than those indicated above, which are in successful use to-day, despite the fact that fuel economy may be increased by higher pressures and temperatures.

The estimate of the performance of plants of type A was based upon the use of No. 3 buckwheat coal having approximately the following characteristics:

Moisture	per cent..	10.8
Volatile matter	do....	4.8
Fixed carbon	do....	71.6
Ash	do....	13.8
British thermal units		11.500

The estimate of the performance of plants of type B was based upon the use of coal from the central Pennsylvania fields having the following characteristics:

Moisture	per cent..	2.5
Volatile matter	do....	24.6
Fixed carbon	do....	66.0
Ash	do....	7.0
British thermal units		14,100

The curves in Plate VIII show two performances, one called "acceptance test conditions," meaning the best possible performance that may be expected from the plant, and one called "annual," meaning the performance considered throughout a year. The "annual" performance was estimated according to actual operating conditions, under which the boiler-room equipment can not be kept clean enough to maintain test results, the turbines are lapped at about 75 to 80 per cent load to protect service, the vacuum varies, inferior coal must be used at times, and the boilers are banked when necessary. These actual operating conditions have a large effect on performance. It is planned to operate the base-load plants with a uniform daily load by shifting the load swings either to the existing steam-electric plants or to such hydroelectric plants as may be found suitable for peak-load operation. On the assumption that the thermal efficiency will increase up to 1930 at the present rate the annual performance represented by these estimates is a fair average for expected performance between 1920 and 1930.

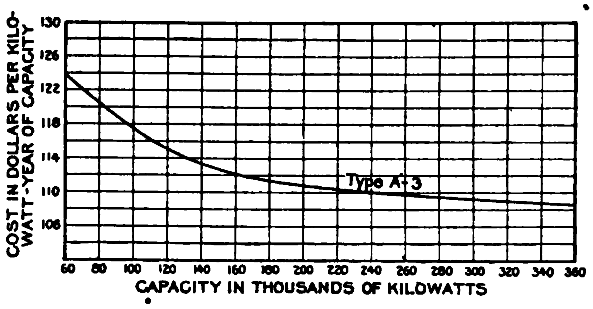


FIGURE 30.—Estimated unit investment cost of base-load steam-electric plants burning anthracite. Based on prices prevailing in midyear of 1919. Type A-3, chain-grate stokers and boilers.

UNIT INVESTMENT COST.

The unit investment costs of plants of the several types considered in figures 30 and 31 are based on the prices of material and labor in the midyear of 1919. These costs will provide sufficient land for a 360,000-kilowatt plant as well as for coal storage and a process coal plant. The main coal-handling system and the main intake and discharge tunnels are adapted to a plant having a minimum capacity of 180,000 kilowatts. Intake and discharge laterals will be added to each unit as turbines are installed. The cost of a 60,000-kilowatt plant therefore includes land sufficient for its development to 360,000 kilowatts and coal-handling facilities and main condenser tunnels for its development to 180,000 kilowatts.

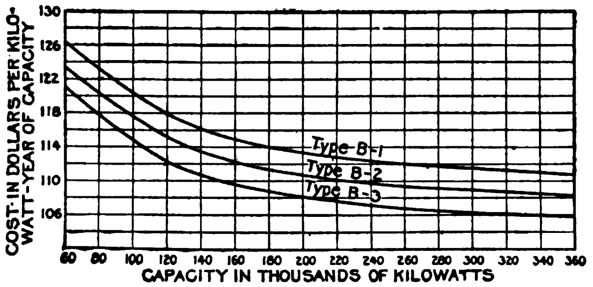
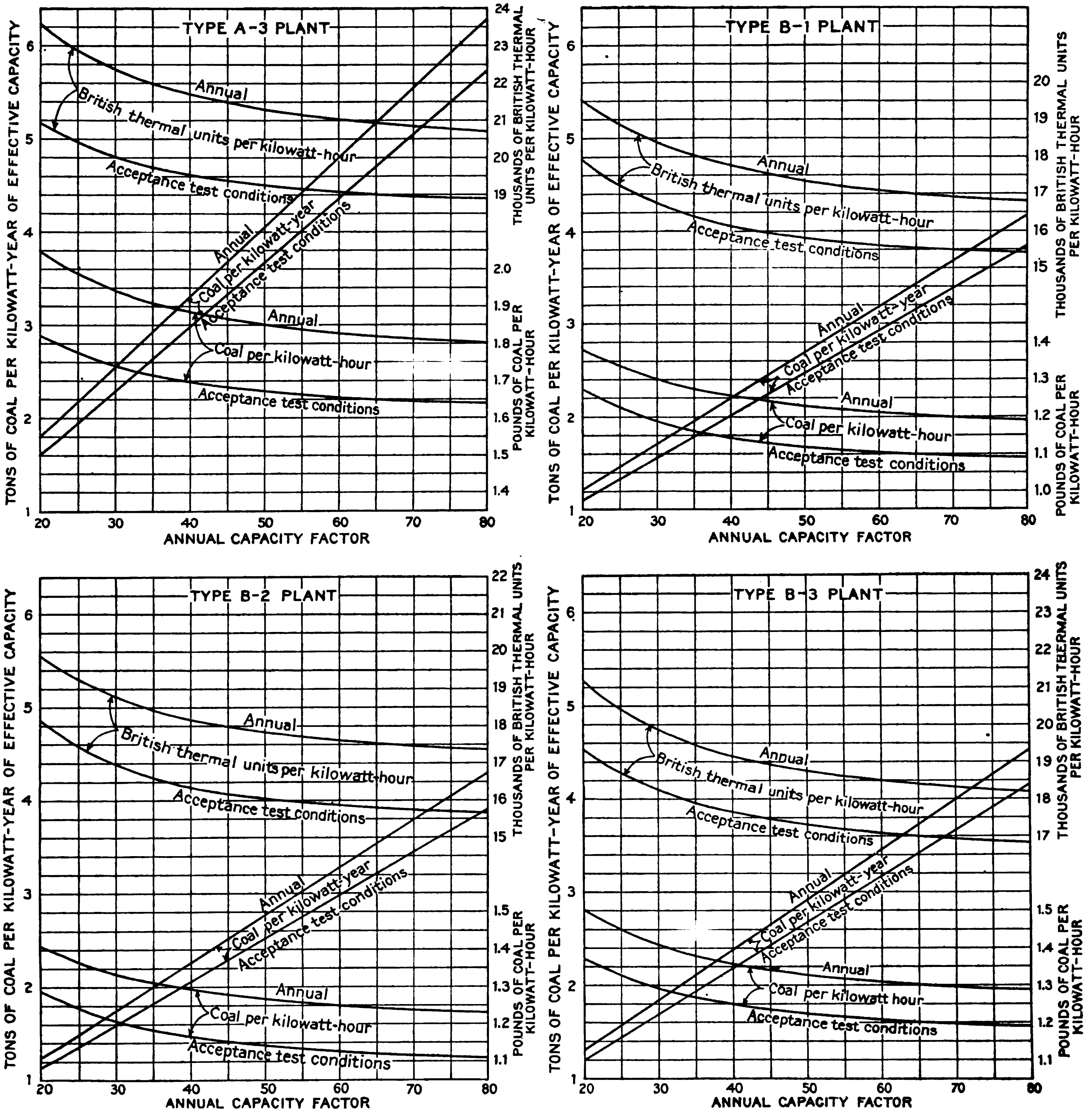


FIGURE 31.—Estimated unit investment cost of base-load steam-electric plants burning bituminous coal. Based on prices prevailing in midyear of 1919. Type B-1, underfeed stokers, boilers, economizers, and preheaters; B-2, underfeed stokers, boilers, and economizers; B-3, underfeed stokers and boilers.

Table 80 shows the estimated cost of three sizes and four types of base-load plants, including the cost of superintendence, engineering, contingencies, and interest during construction.



ESTIMATED UNIT PERFORMANCE OF BASE-LOAD STEAM-ELECTRIC PLANTS.

TABLE 80.—*Estimated unit investment per kilowatt of capacity for base-load steam-electric plants in midyear, 1919.*

Type of plant and capacity in kilowatts.	Real estate and seasonal coal storage.	Boiler house, complete.	Turbine house, complete.	Switching and feeders.	Total.
Type A-3:					
120,000	$3.00	$47.65	$57.20	$7.39	$115.24
240,000	2.10	44.34	56.79	7.37	110.60
360,000	1.80	43.78	55.00	7.36	107.94
Type B-1:					
120,000	3.00	50.10	57.20	7.39	117.69
240,000	2.10	46.71	56.79	7.37	112.89
360,000	1.80	46.13	55.00	7.36	110.29
Type B-2:					
120,000	3.00	47.45	57.20	7.39	115.04
240,000	2.10	44.06	56.79	7.37	110.32
360,000	1.80	43.50	55.00	7.36	107.66
Type B-3:					
120,000	3.00	44.75	57.20	7.39	112.34
240,000	2.10	41.44	56.79	7.37	107.70
360,000	1.80	40.88	55.00	7.36	105.04

UNIT PRODUCTION COST.

Unit production costs are subdivided into operating costs (fuel, maintenance, labor, and supplies) and fixed charges. The costs of maintenance, labor, and supplies for plants using bituminous and anthracite coal, as shown in figure 32, have been determined by detailed analyses of the operations of the largest steam-electric plants in the superpower zone.

The total production cost varies with the type and size of plant and the cost of fuel. Typical costs are shown by the curves in figures 33 and 34 for types B-3 and A-3. The cost of bituminous coal has been fixed at $5.30 per short ton delivered to the plant bunkers, this being the weighted cost for the zone in 1919. The cost of anthracite for plants type A-3 has been fixed at $3 per long ton delivered to the plant bunkers, this being approximately the cost at the anthracite mines plus the freight charge.

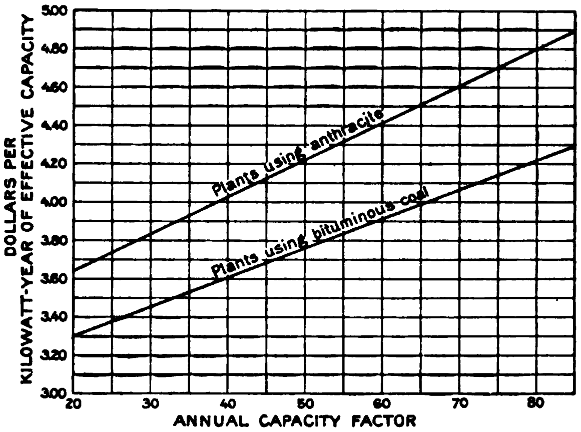


FIGURE 32.—Estimated annual cost of maintenance, labor, and supplies for base-load steam-electric plants. Based on prices prevailing in 1919.

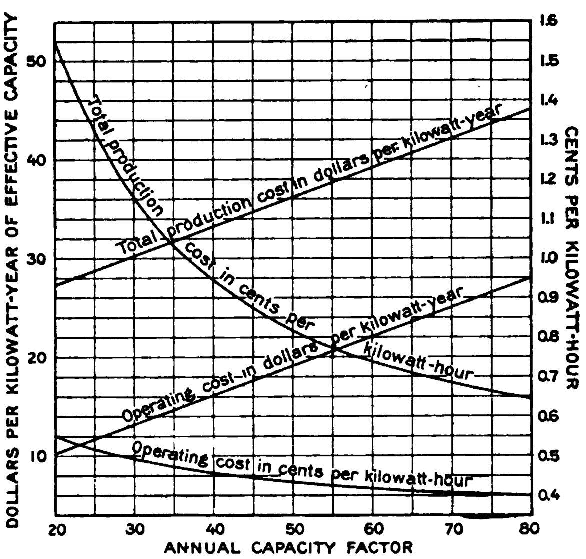


FIGURE 33.—Estimated annual production and operating costs for a plant of type B-3, capacity 300,000 kilowatts. Fuel figured at $5.30 per short ton in bunkers.

Greater fuel economy would be gained by installing plants of high efficiency, but such plants (of classes 1 and 2) cost more per unit, and unless the saving in operating cost is so great as to bring a large return on the additional investment their installation is not warranted. By taking a return of 30 per cent on the additional capital required for plants of classes 1 and 2 over that required for plants of class 3 as the point where the installation of plants of classes

1 and 2 is justified, any notable change in conditions that may occur—such as a large reduction in the cost of coal, the development of water power, or the development of much more efficient methods of power production—is largely discounted, for the additional investment will be counterbalanced in three or four years by the 30 per cent additional return on it.

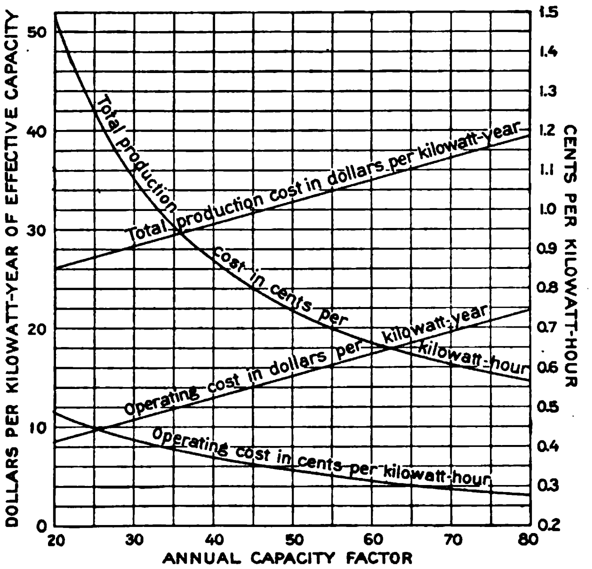


FIGURE 34.—Estimated annual production and operating costs for a plant of type A-3, capacity 300,000 kilowatts. Fuel figured at $3 per long ton in bunkers.

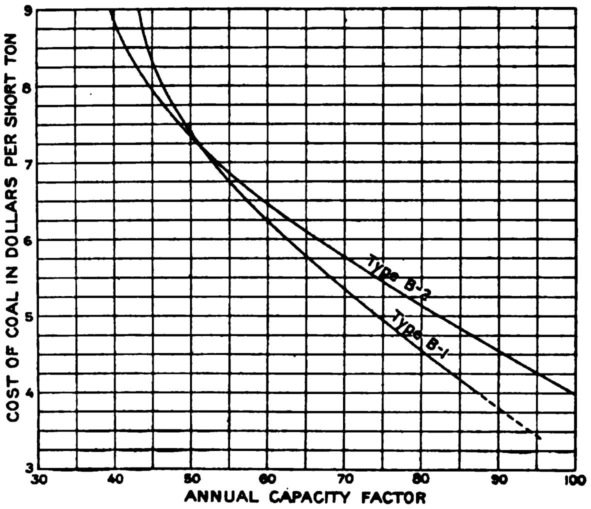


FIGURE 35.—Conditions justifying the use of a plant of type B-1 or B-2 instead of a plant of type B-3. Based on a return of 30 per cent on the additional investment required.

The adoption of plants of different types at different locations has been decided according to the curves in figure 35. The authorities on this subject are of two schools, one advocating a lesser return and the other a greater return than 30 per cent. Figure 35, based upon a 30 per cent return, expresses the average opinion of these two schools.

LOCATION AT TIDEWATER AND ON INLAND RIVERS.

The new base-load steam-electric plants for the superpower system have been so located as to obtain full advantage of low freight rates, available coal-delivery routes, and ample condensing water.

TABLE 81.—*Location and capacity of new base-load steam-electric plants.*

	1925		1930	
	Number of plants.	Capacity (kilowatts).	Number of plants.	Capacity (kilowatts).
Using bituminous coal:				
Boston	1	270,000	2	450,000
New Bedford			1	120,000
Providence	1	180,000	1	240,000
New Haven	1	210,000	1	270,000
Hartford	1	90,000	1	120,000
Utica	1	60,000	1	90,000
Catskill	1	180,000	1	270,000
New York	1	300,000	2	570,000
Newark	1	90,000	1	180,000
Trenton	1	90,000	1	120,000
Philadelphia	1	240,000	2	420,000
Harrisburg	1	120,000	1	180,000
	11	1,830,000	15	3,030,000
Using anthracite:				
Sunbury	1	240,000	1	300,000
Pittston	1	300,000	1	300,000
Nescopeck	1	150,000	1	300,000
	3	690,000	3	900,000
Grand total	14	2,520,000	18	3,930,000

Reference to Appendix E (pp. 164–166) shows that the cost of coal per ton delivered to these proposed new base-load steam-electric plants is lower than to either the steam-electric plants retained or to the electric public utilities for 1919.

The plant locations for 1930 are shown on Plate X (p. 220) with reference to the coal-mining districts, the available coal-delivery routes, and the supply of condensing water. Their locations with respect to the transmission system for both 1925 and 1930 are shown on Plates II and III (p. 14).

For the Anthracite, Metropolitan, and Southern divisions the capacities of the steam-electric power plants have been so determined as to obtain the most economical combination with the hydroelectric plants on Potomac, Susquehanna, and Delaware rivers. Furthermore, the diversity in demand existing between the Anthracite and the Southern and Metropolitan divisions has been considered in determining the capacity of the plants to be installed.

It would have been possible to supply the same amount of power from a smaller number of steam-electric plants having a capacity of about 300,000 kilowatts each, but in order to insure continuity of service the plants have been more widely distributed at a slight increase of cost. However, with such a distribution of plant capacity future demand can be partly met by the enlargement of these plants.

The procedure to be adopted for the development of the hydroelectric resources of the zone has a very important bearing upon the amount of steam-electric capacity to be installed. For instance, in the Mohawk-Hudson division it is proposed to start the development of Hudson River on the assumption of a high load factor, steam-electric plants being used to carry the peak load. This plan calls for the early installation of a relatively large amount of new steam-electric capacity for that division. However, when power from St. Lawrence River is supplied to this division the economical procedure will be to continue the development of Hudson River to handle peak loads and to install practically no further steam-electric capacity until the ultimate limit of development of St. Lawrence and Hudson rivers has been reached.

PLANTS IN THE MINING REGIONS.

The development of electric power within the coal regions is justified when the freight charges on the coal to the points of consumption are greater than the value of the electric energy lost in transmission plus the fixed and operating charges on the transmission system, allowance being made for the saving in capitalization on generating equipment that will be permitted by diversity in loads between the interconnected load centers.

ANTHRACITE FIELDS.

SIZE AND QUALITY OF ANTHRACITE.

Investigation shows that buckwheat No. 3 is the most economical size of anthracite for use on the stokers of superpower plants. The firing of powdered anthracite is being developed but has not yet been brought to the commercial stage. The quality of anthracite from different mines varies, especially as to its ash content. Improved boiler efficiency justifies the cost of ash removal by washing down to a content of about 15 per cent. The performance of steam-electric plants using anthracite is based upon coal having the following analysis: Moisture 9.8 per cent, volatile matter 4.6 per cent, fixed carbon 71.6 per cent, ash 13.8 per cent, British thermal units 11,500.

QUANTITY OF ANTHRACITE AVAILABLE.

Doubtless the peak of production of anthracite was reached during the World War, the output from the mines during that period being reinforced by washeries which reclaimed great quantities of the finer sizes of coal from culm banks. Most of the coal of size No. 3 has now been removed from the banks. There is no indication, however, that there will be any considerable falling off in the production of freshly mined coal for many years, and there is no reason for any appreciable change in the ratio of the smaller sizes to the total output. The statistics of the last few years are therefore a reliable indication of the quantity of buckwheat

No. 3 available for many years. The table given below is taken from a report of the United States Geological Survey on the production of Pennsylvania anthracite in 1919, by F. G. Tryon, supplemented by data obtained from the Anthracite Bureau of Information. The figures in the last column are a close approximation of the total output of buckwheat No. 3, for although no complete records are available upon the size of the fuel used by the mines, data obtained from individual mines indicate that it is almost exclusively buckwheat No. 3.

TABLE 82.—*Anthracite produced in 1916–1919, in long tons.*

Year.	Total.	Mine fuel used for power and heating.[a]	Mine fuel used for power.	Buckwheat No. 3 sold.	Buckwheat No. 3 produced.[b]
1916	78,195,083	8,715,071	7,933,120	3,326,879	11,259,999
1917	88,939,117	9,321,965	8,432,573	3,136,337	11,568,910
1918	88,237,526	9,128,526	8,246,151	5,174,403	13,420,554
1919	78,653,751	8,573,580	7,787,043	2,377,000	10,164,043

[a] Probably almost exclusively buckwheat No. 3.

[b] Determined by assuming that all the mine fuel used for power is buckwheat No. 3.

Estimates of the future supply of buckwheat No. 3 will show some reduction from the above figures, which include coal from washeries. Tryon in the report cited above states that 1,650,000 tons of freshly mined buckwheat No. 3 was sold and 7,721,545 tons of freshly mined fuel was used for mine operations in 1919. It is estimated that the annual production of this size for the next 10 years should average about 9,000,000 tons.

If all the mines are electrified, the coal thus released will be sufficient to serve all the demands for power at the mines and in addition to operate at their full capacity all the public-utility plants that now serve New York City, New Jersey, and the Philadelphia district.

POSSIBLE SITES IN THE ANTHRACITE REGION.

The following streams within the anthracite region have been investigated with reference to their suitability for supplying condensing water: Portions of Susquehanna, Schuylkill, Lackawanna, and Lehigh rivers; Shamokin, Mahonoy, Mahantango, Wiconisco, Wapwallowpen, Nescopeck, Catawissa, and Roaring creeks. All except the Susquehanna have been eliminated because of low flow, contamination, or both. Three sites on Susquehanna River are suggested—one north of Pittston, one near the mouth of Nescopeck Creek, and the third south of Sunbury. At each of these points the water conditions are favorable for a 300,000-kilowatt plant. An adequate supply of suitable coal can be obtained within a radius of 25 miles. The length of haul is a minimum at Pittston.

COST OS ENERGY FROM PLANTS IN THE ANTHRACITE REGION.

Appendix E shows that by 1930 the total energy requirements of the Anthracite division should reach 3,606,000,000 kilowatt-hours, corresponding to a maximum demand of 785,000 kilowatts. The total generating capacity of the public-utility companies now serving the division is 230,000 kilowatts. Minimum operating cost would be obtained by carrying the entire load from the superpower system, but in order to conserve capital the more efficient of the present plants will be retained.

The sizes of the plants and their location in the Anthracite division, together with their relation if interconnected with Delaware River, are discussed in Appendix E. The combination of the plants in the coal-mining region with Delaware River shows the greatest economic possibility to the Anthracite, Metropolitan, and Southern divisions. In view of the fact that the Anthracite division load reaches a maximum in the morning and falls off rapidly after 3 o'clock in the afternoon, there is considerable diversity between this load and the loads in adjacent territories. Furthermore, the anthracite mines operate on an average only 225 days in the year, so there is further diversity between the mines. If there were an interconnected system between the Anthracite and the other divisions considerable off-peak capacity would be available in the Anthracite division for supplying power to the Metropolitan and Southern divisions.

BITUMINOUS COAL FIELDS.

GENERAL CONDITIONS.

On account of the adequate stream flow and the proximity of the Anthracite division to the superpower zone, steam-electric power in that division is an economic possibility. These favorable conditions, however, do not prevail in the bituminous coal region, nor will the power requirement of the southern load centers by 1930 be sufficiently high to permit the economical transmission of power from the bituminous coal fields.

POSSIBLE SITES IN THE BITUMINOUS COAL REGION.

Only three large streams flow from the eastern slope of the Allegheny Mountains—the West Branch of the Susquehanna, the Juniata, and the Potomac. The highest point on Susquehanna River deserving consideration in this connection is at Keating, where Sinnemahoning Creek joins the river. This point is about 20 miles from the Clearfield district, the nearest locality at which an adequate supply of coal can be obtained. The flow at Keating derived from stream-flow records at Renovo indicates that the output during dry periods would be limited to less than 100,000 kilowatts.

Below the junction of the Frankstown and Raystown branches of Juniata River, near Huntingdon, the water supply is insufficient for a plant of a capacity exceeding 180,000 kilowatts. At either Huntingdon or Mount Union railroad facilities are available for obtaining coal from the Broad Top field with a maximum haul of 30 miles, and the distance from Huntingdon to the Philipsburg district is 45 miles.

The West Branch of Potomac River reaches the coal fields near Cumberland, Md. At this point the local power company has a steam plant whose ultimate capacity is limited by the supply of water to about 30,000 kilowatts. About 30 miles below Cumberland, near Green Spring, the South Branch adds a large volume of water, which will permit increasing the capacity to 180,000 kilowatts.

A condition precedent for the economical transmission of power to tidewater is a capacity for delivered power of about 300,000 kilowatts, with transmission at a very high load factor. Sufficient condensing water is not available for the production of this amount of power on any of the streams in the eastern bituminous coal region. This fact, however, does not preclude the future development of power capacity with proper regulation of these rivers by storage. On Potomac River hydroelectric developments are contemplated at Great Falls, near Washington, which involve controlling the river flow by means of large reservoirs on the South Branch. When this plan is carried out the stream flow at the proposed site will be adequate for a 300,000-kilowatt steam plant. Coal for such a plant would come largely from the Georges Creek field, with an average haul of about 35 miles.

Ultimately steam-electric power plants may be profitably developed at sites near the bituminous mines, especially after the electrification of railroads has been extended sufficiently to create considerable demand for power within economical transmission distances from these sites.

APPENDIX G.

HYDROELECTRIC PLANTS FOR THE SUPERPOWER SYSTEM.

By L. E. IMLAY, L. A. WHITSIT, B. J. PETERSON, and others of the engineering staff.

THE USE OF HYDROELECTRIC PLANTS.

The installation of hydroelectric plants is justified where the interest on the investment plus the cost of operation amounts to less than that for steam-electric plants, so that the economical proportions of water and steam development must depend upon the cost of money, coal, and labor.

Hydroelectric plants can be classified as of three types, the type depending upon the character of the stream flow, namely:

1. Uniform stream flow by which the output may be maintained for 24 hours a day.
2. Variable stream flow without storage. A hydroelectric plant of this type is especially useful in a large interconnected system, but less so if it supplies a single system, for then the economical use of water is most difficult, if not impossible. The flow curve of such a river is as clearly defined as the load curve of the power market, and evidently power must be wasted unless either the load curve of the market is coincident with the flow of the river or the market load is sufficiently large to absorb the entire hourly output of the plant. It is obvious that the load of a large interconnected system can absorb the hourly output of a plant of this type.
3. Variable stream flow with storage, which provides water for carrying peak loads. The maximum attainable load factor for the superpower system will probably be 50 per cent. With such a load factor 14 per cent of energy (in kilowatt-hours) will carry a 50 per cent peak load (in kilowatts). It is therefore apparent that the value of water storage will lie in the utilization of the stored kilowatt-hours for carrying peak load, inasmuch as, after the dam and head works of the hydroelectric plant have been installed, the investment in generator capacity is but half as much as that for a complete steam-electric plant. In other words, stored water should be held in reserve for peak load.

POTENTIAL HYDROELECTRIC DEVELOPMENTS.

GENERAL CONSIDERATIONS.

The investigation of potential hydroelectric development is limited to the major hydroelectric resources of the superpower zone and to such outside sources of hydroelectric energy as may be reasonably expected to contribute to it. The principal rivers involved are the Potomac, Susquehanna, Delaware, Hudson, Black, Raquette, Connecticut, St. Lawrence, and Niagara. (See Pl. IX.) The Niagara at Niagara Falls contains the largest single potential hydroelectric power development on the North American continent. It is within transmission distance of the superpower zone, but its development beyond what is already provided for is prevented for an indefinite time by international treaty. All the power resources of the zone are not included in these studies, those below 5,000 kilowatts in capacity being disregarded except where contiguous sites of smaller capacity aggregate more than that amount. These small powers will be developed as local conditions warrant, and the plants will be connected to the superpower system through the facilities of the electric public-utility companies. The superpower system will permit the earlier construction of the smaller plants by providing a market for energy not required locally.

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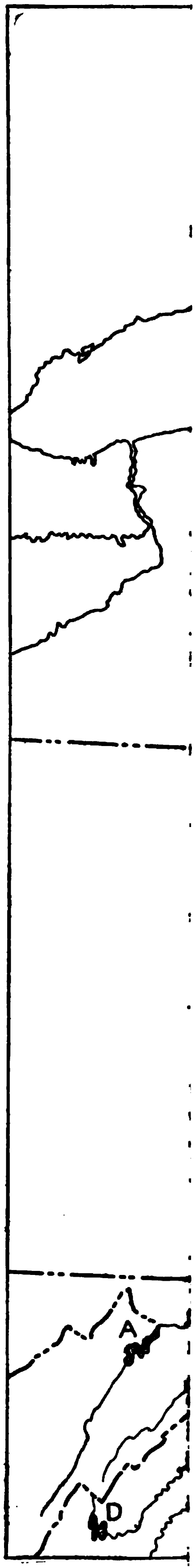


The following table gives a general idea of the characteristics that affect the availability of the rivers for power:

TABLE 83.—*Characteristics of rivers that may furnish power in the superpower zone.*

River.	Point of record.	Natural run-off 50 per cent of the time in year of average stream flow (second-feet).	Lowest recorded daily run-off (second-feet).	Possible continuous regulated flow in average year (second-feet).	Total drainage area (square miles).	Fall available for power development (feet).
Potomac	Great Falls[a]	6,500	660	7,650	11,500	215
Susquehanna	Harrisburg	19,500	2,000	....	24,100	220
Delaware	Port Jervis	3,100	175	4,600	3,100	600
Hudson	Spier Falls	3,000	([b])	4,200	2,800	1,500
Raquette	Piercefield	900	([b])	1,430	723	1,360
Connecticut	Sunderland	8,160	[c] 1,330	....	8,000	[d] 378
St. Lawrence	Lock 23	235,000	[e] 182,000	....	285,000	85
Niagara		212,000	170,000	....	254,700	310

[a] Flow at Great Falls determined from records of flow of Potomac River at Point of Rocks, Md., and Monocacy River near Frederick, Md.
[b] Stream flow affected by operation of power plant.
[c] Mean of low week September, 1894, determined from records of flow at Holyoke. Flow somewhat affected by existing plants.
[d] Net head used in report.
[e] Mean for January, 1893.

All these streams except the St. Lawrence and Niagara rise in the Appalachian Mountains. The fall indicated as available for power development in most of the rivers is but a small fraction of the total fall. The developments proposed are practical.

The following table indicates the hydroelectric power resources that are considered economical for supplying the energy requirements of the superpower zone in 1930:

TABLE 84.—*Hydroelectric power resources for 1930.*

River.	Number of plants.	Primary power (kilowatts).	24-hour power (kilowatt-hours).	Economical development (kilowatts).
Potomac	2	34,500	302,000,000	200,000
Susquehanna	2	18,000	158,000,000	185,000
Delaware	12	82,000	717,000,000	350,000
Hudson	14	68,000	595,000,000	150,000
Connecticut	4	29,000	254,000,000	165,000

The quantity of water available for the production of power at the several sites was determined from stream-flow measurements made by the United States Geological Survey or by the State governments. The period of record used for most of the power estimates was 15 years and extended from October 1, 1904, to September 30, 1919. The power and reservoir sites were located from State reports, reports of private engineers, topographic drawings, and personal investigation by the engineering staff. Stream-flow and power-duration curves for reservoir and power sites were plotted for average and minimum years.

Development of primary power on all the streams under consideration, except the Niagara and St. Lawrence, involves the provision of large storage-reservoir capacity. There must be in addition ample forebay capacity at each power plant for peak-load operation. The construction of hydroelectric plants for base-load operations results in the lowest investment and production cost, and additional capacity for peak-load operation is obtained at about one-half the cost of an equivalent amount of steam-generating capacity.

The developments proposed in the estimates for 1925 and 1930 can be justified only if they are included in an interconnected system, as otherwise their output can not be economically absorbed by the power market.

For the rivers that are not included in the 1921–1930 program estimates are given showing the resources that can be developed in average years, together with the investment and production costs.

At practically all sites where hydroelectric plants are designed for peak-load operation there are considerable periods during each year when there is sufficient water to generate energy in excess of peak-load requirements. At such times the hydroelectric plants will be operated at full capacity, thus saving coal that would otherwise be burned in the steam plants of the system.

The recommended capacity for most of the proposed hydroelectric plants is larger than has been recommended in the past for use with individual electric public-utility systems. This is possible only through the interconnected system, which permits full advantage to be taken of peak-load development and of secondary power from hydroelectric plants.

In estimating the over-all efficiency of hydroelectric plants 80 per cent has been taken as the combined efficiency of turbines, generators, and auxiliary equipment and is applied to the net operating head between forebay and tail race.

POTOMAC RIVER.

The Potomac rises in the mountains of West Virginia and flows into Chesapeake Bay. It is not regulated to any appreciable extent, and the flow at Great Falls ranges from 653 to 248,000 second-feet and averages 11,900 second-feet. The drainage area is 11,500 square miles, and the annual rainfall is between 35 and 40 inches. The fall from Point of Rocks, Md., to tidewater near the boundary line of the District of Columbia is 204 feet, of which 151 feet is below the aqueduct dam at Great Falls, 10.5 miles above the District line.

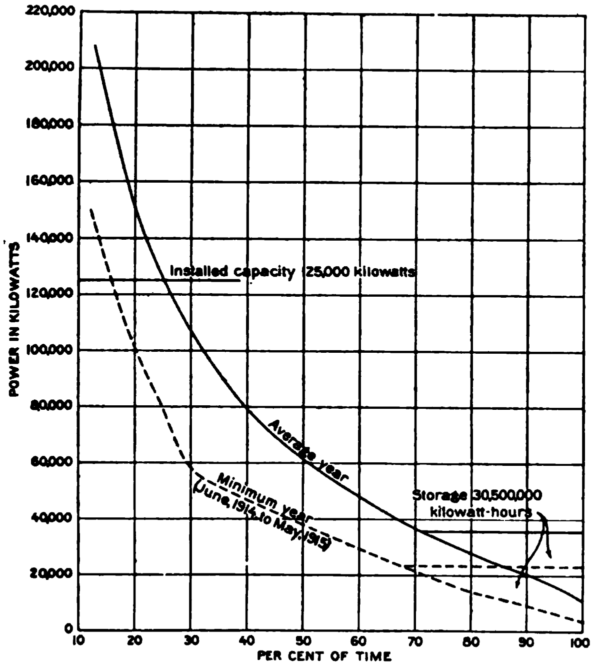


FIGURE 36.—Estimated power available from proposed hydroelectric development of Potomac River for 1925. Total power, average year, 634,000,000 kilowatt-hours; minimum year, 480,000,000 kilowatt-hours. Power site 1 (Pl. IX).

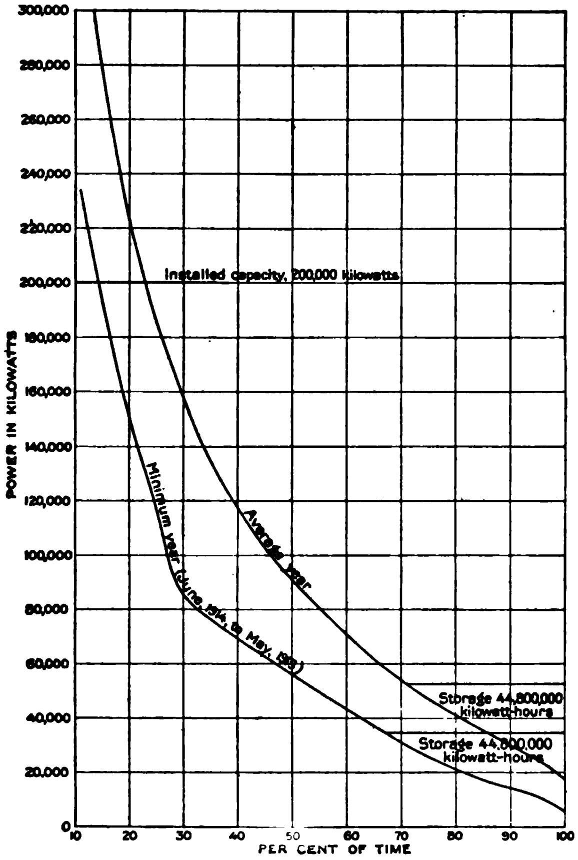


FIGURE 37.—Estimated power available from proposed hydroelectric development of Potomac River for 1930. Total power, average year, 950,000,000 kilowatt-hours; minimum year, 725,000,000 kilowatt-hours. Power sites 1 and 2 (Pl. IX).

There are sites available for storage reservoirs on Great Cacapon River, a tributary stream, where the capacity is 15.6 billion cubic feet; on North Fork of Shenandoah River near Brocks Gap, where the capacity is 4.8 billion cubic feet; farther downstream on Shenandoah River, where the capacity is 11.2 billion feet; and on the South Branch of the Potomac near its junction with the main river, where the capacity is 20.2 billion cubic feet. Furthermore, the dam at Great Falls will provide a combined storage reservoir and forebay with a capacity of 13.1 billion cubic feet, making a total storage capacity of 65 billion cubic feet.

The most favorable locations for power development are at Great Falls and Chain Bridge, where, by the construction of two dams, a head of 215 feet may be utilized. (For duration of flow expressed in kilowatts at these power sites see figs. 36 and 37.) The following table gives the essential data on this project, which includes the two plants, with necessary reservoir capacity:

TABLE 85.—*Power development on Potomac River.*

	Proposed development.		Possible ultimate development.
	1925	1930	
Reservoir capacity billion cubic feet	13.07	13.07	64.97
Operating head feet	139.5	205	205
Installed generator capacity kilowatts	125,000	200,000	600,000
Output:			
Average year kilowatt-hours	634,000,000	950,000,000	1,370,000,000
Minimum year do	480,000,000	725,000,000	1,030,000,000
Investment cost	$15,000,000	$22,000,000	$60,000,000
Annual production cost	$2,165,000	$3,190,000	$8,790,000
General expense	75,000	110,000	310,000
Total annual cost	2,240,000	3,300,000	9,100,000
Time required to complete years	2	2	3

SUSQUEHANNA RIVER.

The Susquehanna has its headwaters in southern New York and in the highlands of northwestern Pennsylvania and empties into Chesapeake Bay. The drainage area above Harrisburg is 24,100 square miles, and the flow at that point ranges from 2,000 to 700,000 second-feet and averages 19,500 second-feet. The average annual rainfall on the area is 40 inches. In the lower 35 miles of the course of the river there is a fall of 220 feet so distributed that most of it may be utilized for power at four points—Conestoga, Holtwood, Conowingo, and a point about 2 miles above Port Deposit. There is already a power plant at Holtwood, which may be advantageously enlarged when the demand for power justifies it. (For duration of flow expressed in second-feet per square mile at Harrisburg, see fig. 38.)

The Susquehanna has no favorable sites for storage reservoirs and therefore must be developed for "run of river" power. Power development at the Conowingo site is hampered by the fact that the railroad parallels the stream just above high-water level, and thus large expenditure would be required for relocating railroad tracks.

The following table gives the data on development of the river at the four points above mentioned:

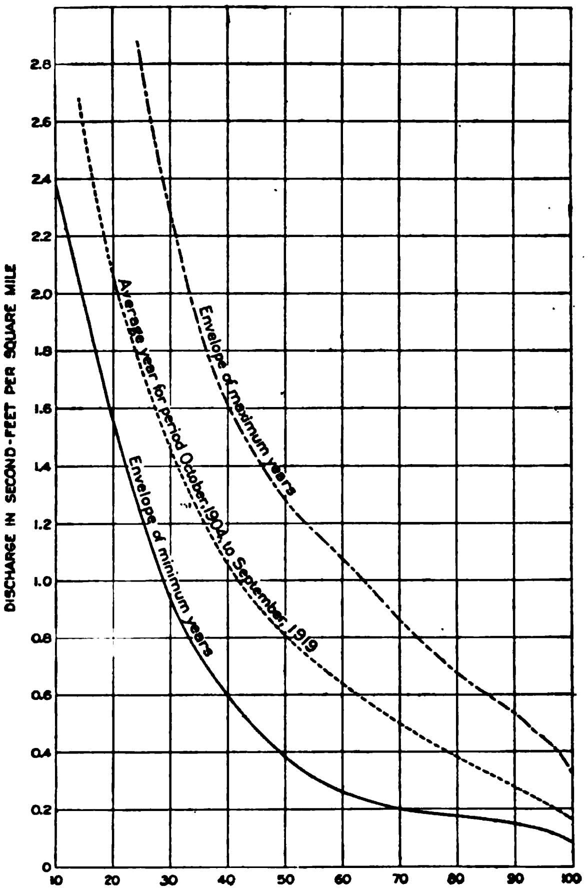


FIGURE 38.—Curves showing duration of flow of Susquehanna River at Harrisburg, Pa. Drainage area, 24,100 square miles.

TABLE 86.—*Power development on Susquehanna River.*

	Proposed development.		Possible ultimate development.
	1925	1930	
Total operating head, including Holtwood..........feet..	131	174	204
Installed new generating capacity..........kilowatts..	120,000	185,000	620,000
Output:			
Average year..........kilowatt-hours..	800,000,000	1,230,000,000	2,700,000,000
Minimum year..........do....	580,000,000	900,000,000	1,850,000,000
Investment cost..........	$18,000,000	$28,000,000	$64,000,000
Annual production cost..........	$2,510,000	$3,961,000	$9,484,568
General expense..........	90,000	139,000	335,432
Total annual cost..........	2,600,000	4,100,000	9,820,000
Time required to complete..........years..	2	2	2

DELAWARE RIVER.

The headwaters of Delaware River are in the Catskill Mountains, and it empties into Delaware Bay. The drainage area above Port Jervis is 3,100 square miles, and the natural stream flow at that point ranged from 175 second-feet in September, 1908, to a maximum of 108,000 second-feet in February, 1909. The average annual rainfall on the area is about 40 inches. Between Hancock and Belvidere, a distance of 125 miles, there is a fall of 600 feet. The development proposed is to be effected by means of a series of dams, each of which will back up the water to the next site above. It is proposed ultimately to develop 12 sites on the main river, one on Wallenpaupack Creek, one on Shohola Creek, and one on Mongaup River. On the Delaware also power development is hampered by the presence of railroad tracks along the banks of the stream, but in the proposals for development the height of dams has been restricted

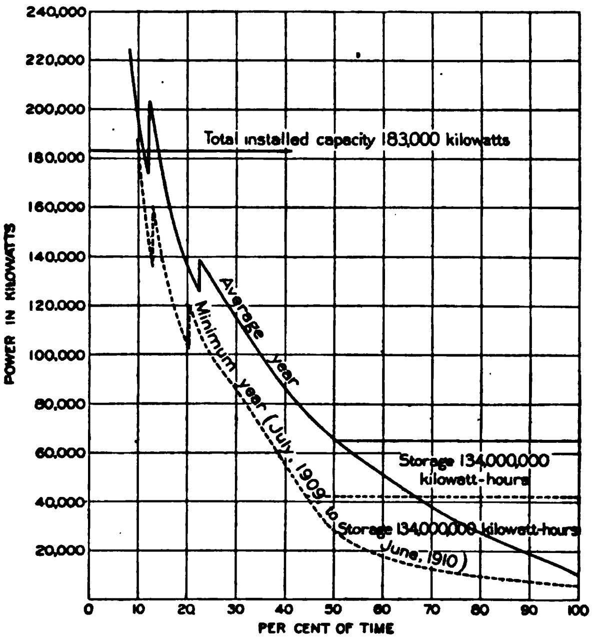


FIGURE 39.—Estimated power available from proposed hydroelectric development of Delaware River for 1925. Total power, average year, 850,000,000 kilowatt-hours; minimum year, 650,000,000 kilowatt-hours. Reservoir A (Pl. IX), 12 billion cubic feet. Power sites 6 (storage 7.5 billion cubic feet), 7, 10, 12, 13, 15, 16 (Pl. IX).

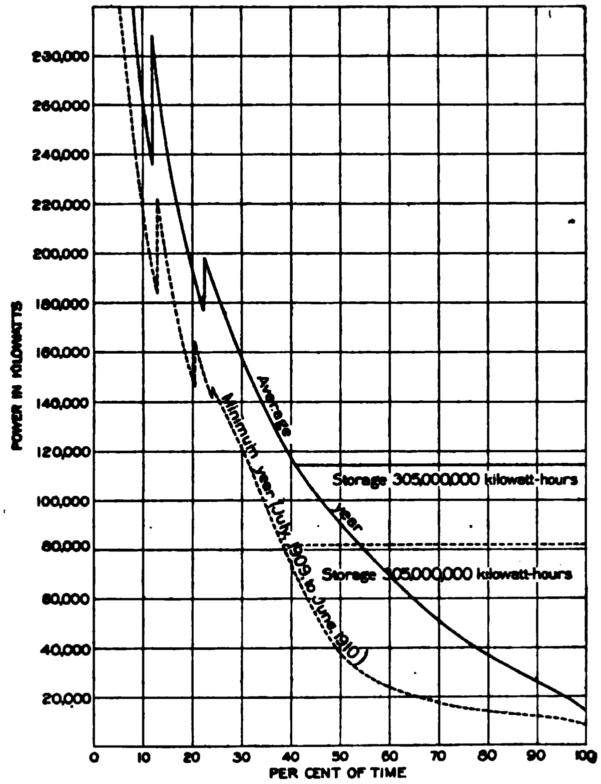


FIGURE 40.—Estimated power available from proposed hydroelectric development of Delaware River for 1930. Total power, average year, 1,250,000,000 kilowatt-hours; minimum year, 1,030,000,000 kilowatt-hours. Reservoirs A (Pl. IX), 12 billion cubic feet; B, 5 billion cubic feet; D, 8 billion cubic feet; E, 3 billion cubic feet. Power sites 1, 2, 4, 5, 6 (storage 7.5 billion cubic feet), 7, 10, 12, 13, 14, 15, 16 (Pl. IX). Total storage 35.5 billion cubic feet.

so that only at one site will the grade of the railroad have to be changed. The power plants on the Delaware will be located at the dams, but for those on the three tributary streams tunnels will be required.

Owing to the wide variation in the flow of this river storage reservoirs will be absolutely necessary in its development. There are a number of favorable sites on the east and west branches above Hancock, and also one on each of the tributary streams on which developments are proposed. A capacity of 50 billion cubic feet can be provided in eight reservoirs, which are shown on Plate IX. Practically all the sites have a forebay capacity which will enable the plants to be operated on peak loads at a low capacity factor. (For duration of flow expressed in kilowatts at these power sites see figs. 39 and 40.)

The following table gives the data on development of Delaware River and its tributaries:

TABLE 87.—*Power development on Delaware River.*

	Proposed development.		Possible ultimate development.
	1925	1930	
Reservoir capacity....billion cubic feet..	19.5	35.5	50.0
Total operating head, Delaware River....feet..	279	453	471
Head on Wallenpaupack Creek....do....	280	280	280
Head on Shohola Creek....do....	....	....	580
Head on Mongaup River....do....	....	....	430
Total installed generator capacity....kilowatts..	183,000	350,000	668,500
Output:			
Average year....kilowatt-hours..	850,000,000	1,250,000,000	1,490,000,000
Minimum year....do....	650,000,000	985,000,000	1,210,000,000
Investment cost....	$25,700,000	$51,500,000	$86,500,000
Annual production cost....	$3,730,000	$7,450,000	$12,630,000
General expense....	130,000	260,000	440,000
Total annual cost....	3,860,000	7,710,000	13,070,000
Time required to complete....years..	2	2	4

HUDSON RIVER.

Hudson River rises in the Adirondack Mountains and empties into the Atlantic Ocean at New York. The drainage area at Spier Falls is 2,800 square miles and at Troy 8,100 square miles. The stream flow at Spier Falls ranged from 660 second-feet, the mean for the low week in September, 1913, to 84,200 second-feet in March, 1913. The average annual rainfall on the area is about 45 inches. There is a gross fall of 975 feet between Ort Falls and Hadley. A large number of hydroelectric plants have been built on the Hudson, and complete development would involve about 16 new plants and reconstruction or replacement of 14 existing plants. (For duration of flow expressed in kilowatts at these power sites see figs. 41 and 42, p. 198.)

There are four available storage reservoir sites—Lake Piseco, 4.3 billion cubic feet; Sacandaga River at Conklingville, 37 billion cubic feet; Schroon Lake at Alder Brook, 12 billion cubic feet; and Indian River at Bullhead Pond, 10 billion cubic feet; total, 63.3 billion cubic feet.

TABLE 88.—*Power development on Hudson River.*

	Proposed development.		Possible ultimate development.
	1925	1930	
Reservoir capacity....billion cubic feet..	[a] 10	[a] 10	[a] 63.3
Installed generator capacity....kilowatts..	100,000	150,000	430,000
Output:			
Average year....kilowatt-hours..	380,000,000	900,000,000	1,560,000,000
Minimum year....do....	330,000,000	800,000,000	1,370,000,000
Investment cost....	$20,124,000	$38,350,000	$74,384,000
Annual production cost....	$2,815,000	$5,250,000	$10,520,000
General expense....	99,000	200,000	370,000
Total annual cost....	2,914,000	5,450,000	10,890,000
Time required to complete....years..	2	2	3

[a] Gross capacity including present storage of 4.6 billion cubic feet.

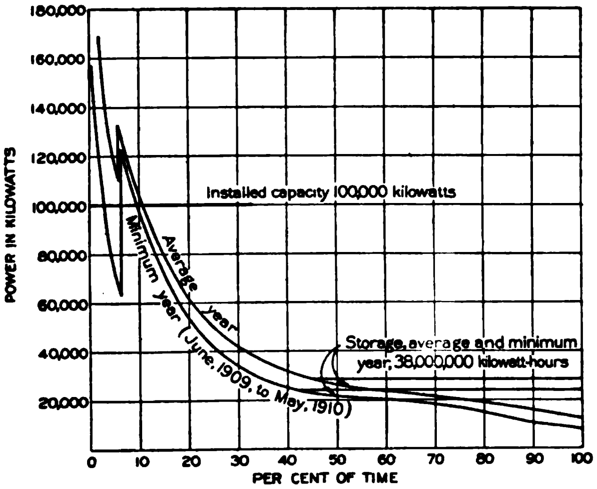


Figure 41.—Estimated power available from proposed hydroelectric development of Hudson River for 1925. Total power, average year, 380,000,000 kilowatt-hours; minimum year, 330,000,000 kilowatt-hours. Reservoir A (Pl. IX), net increased storage 5.1 billion cubic feet. Power sites 7, 8, 9, 10, 11 (Pl. IX).

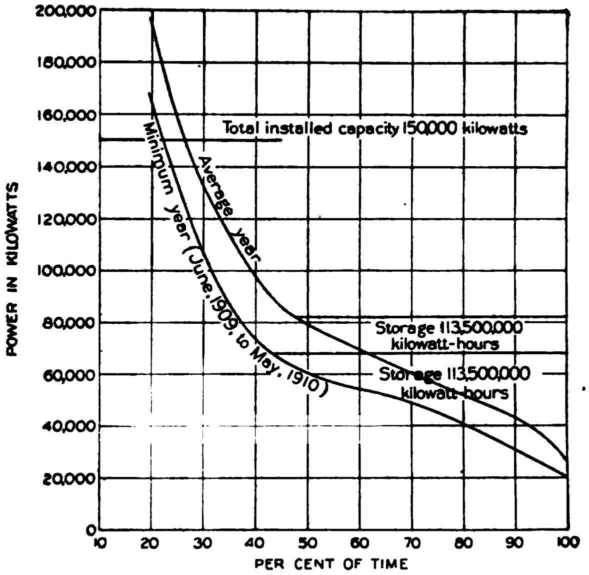


Figure 42.—Estimated power available from proposed hydroelectric development of Hudson River for 1930. Total power, average year, 900,000,000 kilowatt-hours; minimum year, 800,000,000 kilowatt-hours. Reservoir A (Pl. IX), net increased storage 5.1 billion cubic feet. Power sites 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 14, 16, 17 (Pl. IX).

RAQUETTE RIVER.

Raquette River rises in the Adirondack Mountains and empties into the St. Lawrence near Cornwall. The drainage area at Raymondsville is 1,070 square miles, and the stream flow at Piercefield ranged from 58 second-feet, the mean for the low two-week period in September, 1913, to 6,970 second-feet in April, 1913. The average annual rainfall on the area is 48 inches. In 72 miles of this river between Piercefield and Raymondsville there is a fall of 1,350 feet.

The drainage area of Raquette River contains a number of natural lakes, which may be developed into storage reservoirs by the construction of dams at their outlets. It is estimated that 16 billion cubic feet of water may be stored in this manner.

The following statement gives the data of development for Raquette River at 15 sites, at some of which reconstruction of existing plants will be required.

Table 89.—*Possible ultimate power development on Raquette River.*

Reservoir capacity	billion cubic feet	16.0
Total net head	feet	938
New installed generator capacity	kilowatts	110,000
Net output:		
Average year	kilowatt-hours	800,000,000
Minimum year	do	670,000,000
Investment cost		$26,500,000
Annual production cost		$3,745,000
General expense		130,000
Total annual cost		3,875,000

BLACK RIVER.

Black River rises in the Adirondack Mountains, flows westward, and empties into Lake Ontario near Sacketts Harbor. The drainage area above Felt Mills is 1,851 square miles. The stream flow is affected by artificial regulation and has ranged from 400 second-feet, the mean for the low week, to 32,166 second-feet. The average annual rainfall on the area is about 45 inches. On Black River proper the main fall is one of 480 feet between Dexter and Carthage, a distance of 31 miles. Beaver River, a tributary, has a fall of 1,024 feet in 55 miles, and Moose River, another tributary, has a fall of 1,087 feet in 45 miles.

A large number of small lakes in the Adirondack Mountains form natural storage reservoirs, and it is proposed to improve these at six sites on Black River and its tributaries to provide an ultimate storage capacity of 21.5 billion cubic feet.

There are 33 existing power plants in this drainage basin, most of which are used for making paper pulp. There are 11 undeveloped sites on Black River and its tributaries.

The following statement gives the data on these developments and includes estimates for the reconstruction of such existing plants as may be justified and for increasing the reservoir capacity 20 billion cubic feet.

TABLE 90.—*Possible ultimate power development on Black River.*

Reservoir capacity (including 1.5 billion cubic feet of existing storage)	billion cubic feet	21.5
New installed generator capacity	kilowatts	80,000
Output:		
Average year	kilowatt hours	350,000,000
Minimum year	do	315,000,000
Total investment cost		$16,500,000
Annual production cost		$2,290,000
General expense		80,000
Total annual cost		2,370,000
Time required to complete	years	2

CONNECTICUT RIVER.

Connecticut River rises in the Province of Quebec, Canada, and flows into Long Island Sound about 60 miles east of New Haven. The drainage area is 8,000 square miles, and the stream flow at Sunderland, Mass., ranged from 1,330 second-feet, the mean for the low week in September, 1894, to 110,000 second-feet in April, 1895. Between Fifteen Mile Falls, N. H., and Windsor Locks, Conn., there is an aggregate usable fall of 428 feet, including redevelopment of the Bellows Falls site but excluding other developed sites. This fall is divided as follows: Fifteen

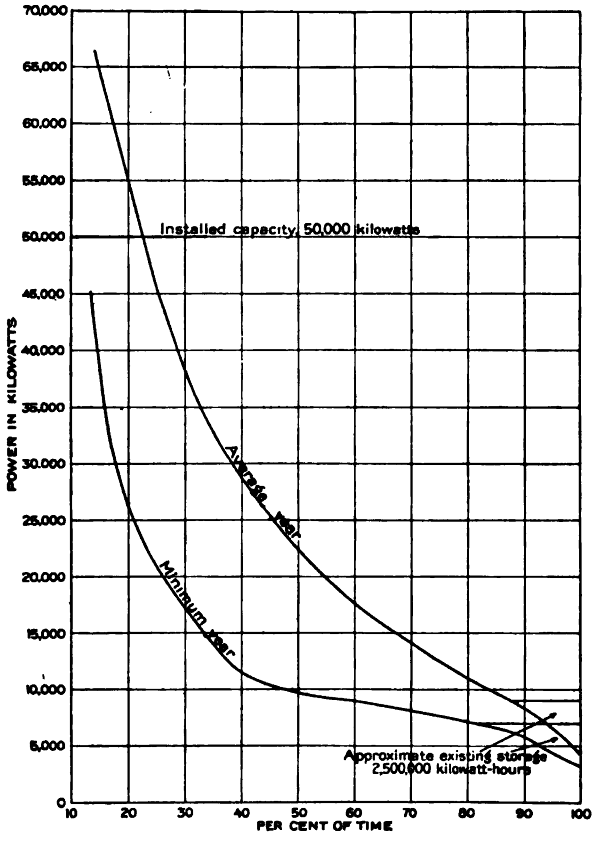


FIGURE 43.—Estimated power available from proposed hydroelectric development of Connecticut River for 1925. Total power, exclusive of storage, average year, 230,000,000 kilowatt-hours; minimum year, 150,000,000 kilowatt-hours. Power site 5 (Pl. IX).

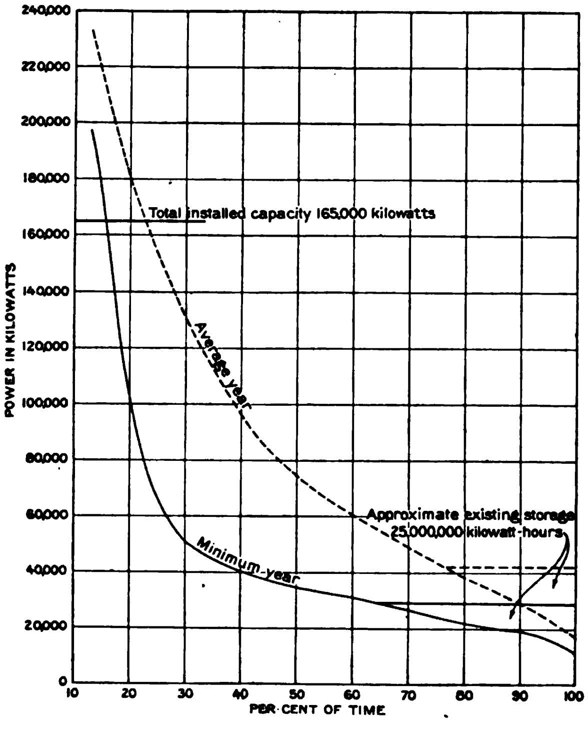


FIGURE 44.—Estimated power available from proposed hydroelectric development of Connecticut River for 1930. Total power, exclusive of storage, average year, 760,000,000 kilowatt-hours; minimum year, 510,000,000 kilowatt-hours. Power sites 1, 3, 4, 5 (Pl. IX).

Mile Falls, 250 feet; Piermont, 50 feet; Quechee Falls, 45 feet; Bellows Falls, 50 feet; Windsor Locks, 33 feet. (For duration of flow expressed in kilowatts at these power sites see figs. 43–45.)

A small amount of storage has been developed and is now used for logging operations and for the development of power. The conditions are favorable for the development of additional storage, which will not only benefit new plants but greatly improve operating conditions at existing plants.

The following table gives data on potential developments at five power sites, which include redevelopment of the Bellows Falls site. The statement does not include additional reservoir capacity:

TABLE 91.—*Power development on Connecticut River.*

	Proposed development.		Possible ultimate development without storage.
	1925	1930	
Total operating head..........feet..	33	428	428
Installed generator capacity..........kilowatts..	50,000	165,000	165,000
Output:			
Average year..........kilowatt-hours..	230,000,000	760,000,000	760,000,000
Minimum year..........do....	150,000,000	510,000,000	510,000,000
Investment cost..........	$9,000,000	$29,000,000	$29,000,000
Annual production cost..........	$1,256,000	$4,130,000	$4,130,000
General expense..........	44,000	140,000	140,000
Total annual cost..........	1,300,000	4,270,000	4,270,000

ST. LAWRENCE RIVER.

The portion of St. Lawrence River here considered lies between Lake Ontario and a point near Cornwall, where the international boundary diverges from the river in an easterly direction. An investigation is now being made by engineers of the United States and Canadian governments looking to the development of the river in the vicinity of Long Sault and Barnhardts Island. The fall available is about 80 feet, and it is estimated that generating capacity of about 1,200,000 kilowatts can be installed to yield an annual output of more than 10,000,000,000 kilowatt-hours. It is assumed that the ownership of one-half of this output will be allocated to the United States Government. The outstanding feature of this development is that the storage capacity of the Great Lakes, which drain an area of 278,700 square miles, furnishes almost complete regulation of the river flow. The lowest recorded average flow for a month is 186,000 second-feet, which is about 80 per cent of the average continuous flow.

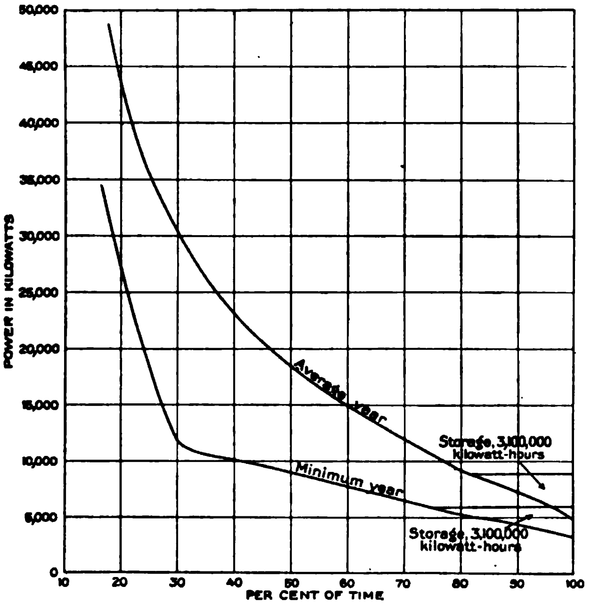


FIGURE 45.—Curves showing duration of power on Connecticut River at Bellows Falls, Vt.

No estimate of the cost of development will be given here, as such an estimate is now being made by the engineers of the two governments. The cost, however, should be lower per unit than that of any of the developments on which estimates are given in this report, on account of the size of the development and because a large portion of the expenditure will be made for the improvement of navigation.

NIAGARA RIVER.

Niagara River is about 30 miles in length and drains Lake Erie into Lake Ontario. The difference in elevation between these two lakes is about 330 feet. The fall between Lake Erie and the river level at the beginning of the rapids above the main falls is 9 feet, between this point and the middle pool below the falls 220 feet, and between the middle pool and Lake Ontario 101 feet. The characteristics of stream flow are much the same as those of the St. Lawrence, but the flow is subject to daily variations due to wind.

The water that can be diverted at Niagara Falls for the generation of power is now limited by international treaty to 20,000 second-feet on the American side of the river and to 36,000 second-feet on the Canadian side. Practically the whole of this permitted diversion has been made, and no further developments are possible so long as the present treaty is in force. It may be abrogated on one year's notice from either party.

The question of additional diversion of water from the river for power is somewhat complicated with the navigation of Lake Erie, as any large increase in diversion will tend to lower the lake level. By the construction of remedial works at the outlet of Lake Erie, however, it will be practicable to increase the amount of water diverted for power without impairing the navigability of the lake. The scenic beauty of the falls may be preserved by constructing works that will distribute the flow more uniformly over the crest. This power would probably be cheaper to develop than St. Lawrence power and would be equally available for use in the superpower zone.

THE RIVERS OF MAINE.

In addition to the resources described above there is considerable undeveloped power in the State of Maine which is within transmission distance of the northeastern part of the superpower zone. As hydroelectric energy generated in Maine can not, under the present laws of that State, be transmitted outside its boundaries, these potential developments have not been analyzed in detail.

The following figures taken from the report of a special water-power investigation by the Public Utilities Commission of Maine for 1918 give an idea of the magnitude of these resources:

TABLE 92.—*Water-power resources of Maine.*

[Horsepower available for 95 per cent of an average year.]

River.	Present conditions.			Conditions after regulation.		
	Developed.	Undeveloped.	Total.	Developed.	Undeveloped.	Total.
Fish	....	3,600	3,600	....	6,400	6,400
Allagash	....	3,600	3,600	....	8,600	8,600
Presumpscot	5,400	....	5,400	10,000	....	10,000
St. Croix	13,000	4,000	17,000	14,000	4,000	18,000
Union	1,600	....	1,600	5,000	....	5,000
Kennebec	26,000	50,000	76,000	56,000	105,000	161,000
Saco	11,000	7,000	18,000	24,000	15,000	39,000
Androscoggin	77,800	28,000	105,800	85,000	31,000	115,000
Penobscot	92,000	47,000	139,000	110,000	67,000	177,000
	226,000	143,200	370,000	310,000	237,000	547,000

CAPACITY AND OUTPUT OF EXISTING HYDROELECTRIC PLANTS.

The following table shows the location of hydroelectric generating capacity in operation in the superpower zone and its output for 1919. The table gives an estimate of the capacity that can be furnished for the annual peak under low-water conditions and the annual output for the average and minumum year.

TABLE 93.—*Hydroelectric plants in superpower zone.*

Division.	Installed generator capacity (kilowatts).	1919 output (millions of kilowatt-hours).	Annual peak capacity (kilowatts).	Output (kilowatt-hours).	
				Average year.	Minimum year.
Eastern New England	96,000	292.54	42,835	269,020,000	190,615,000
Western New England	111,530	303.45	51,130	340,015,000	223,650,000
Mohawk	116,150	390.41	45,110	341,450,000	275,020,000
Metropolitan	8,710	24.70	865	22,120,000	14,715,000
Hudson	8,690	22.80	2,415	19,980,000	15,990,000
Anthracite	5,080	17.22	660	16,054,000	12,987,000
Southern	105,340	612.07	53,720	548,790,000	384,630,000
	451,500	1,663.19	196,735	1,557,429,000	1,117,607,000

UNIT AND TOTAL INVESTMENT COST.

The unit investment cost for hydroelectric generating equipment is given in figure 46 for operating heads of 20, 40, 80, 120, and 400 feet and for generating units ranging in size from 5,000 to 30,000 kilowatts. These unit costs are based on prices in the midyear of 1919 and include turbines, generators, low-tension switch gear, wiring erected, interest during construction, superintendence, engineering, and contingent expenses. They are applicable to all units except those first installed, for which 8 per cent must be added to cover development charges. The unit costs were compiled from information furnished by the principal manufacturing companies in this country.

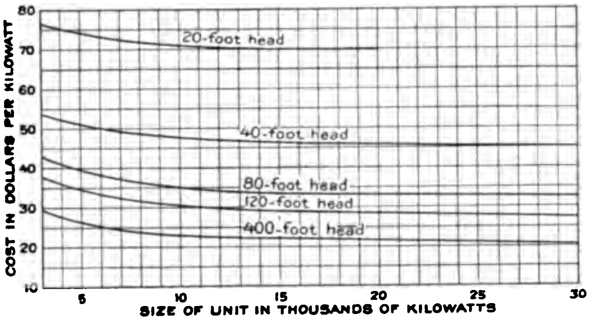


FIGURE 46.—Unit cost for complete hydroelectric equipment installed, for different operating heads in midyear of 1919. Includes turbines, generators, low-tension switch gear and wiring, interest during construction, superintendence, engineering, and contingencies. A development charge of 8 per cent against the first unit should be added.

In estimating the reproduction cost of the existing hydroelectric generating plants as shown below consideration was given to the size of the plant, the operating head, and the other characteristics of individual plants, and the estimates were checked by data furnished by the owners.

Eastern New England	$16,501,000
Western New England	16,713,000
Mohawk	24,442,000
Metropolitan	2,550,000
Hudson	$1,693,000
Anthracite	1,265,000
Southern	23,963,000
	87,127,000

ANNUAL OPERATING COST PER UNIT.

In order to determine annual unit operating costs, comprehensive records of 58 hydroelectric plants were selected for analysis. Figure 47 shows the cost per kilowatt-year of total generator capacity plotted against the size of the unit. Figure 48 shows the cost per kilowatt-year of total generator capacity plotted against the capacity of the plant. The use of these two curves in conjunction gives operating cost for power plants employing units of different sizes.

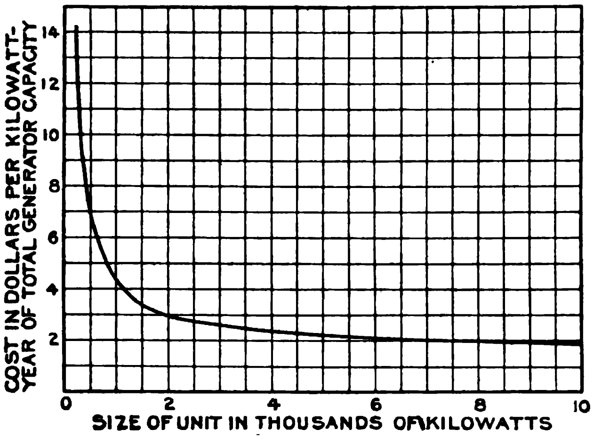


FIGURE 47.—Unit operating cost of 58 selected hydroelectric plants in the superpower zone, 1919, according to size of unit.

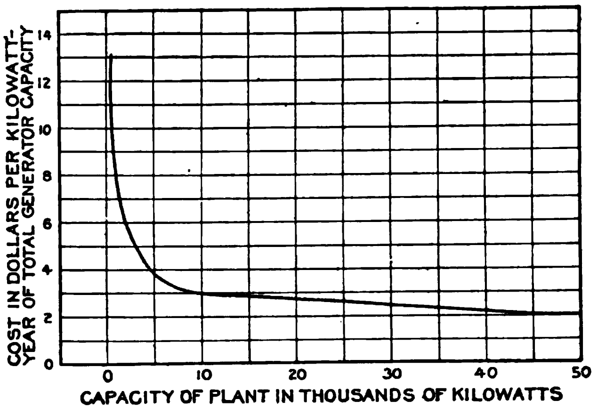


FIGURE 48.—Unit operating cost of 58 selected hydroelectric plants in the superpower zone, 1919, according to capacity of plant.

APPENDIX H.

THE SUPERPOWER TRANSMISSION SYSTEM.

By L. E. Imlay.

EXISTING TRANSMISSION SYSTEMS.

The mileage of the transmission lines above 30,000 volts in the superpower zone in 1919 amounted to 1,200 miles, 37 at 110,000 volts, 813 at 66,000 volts, 36 at 44,000 volts, and 314 at 33,000 volts. Of these 1,200 miles New England has 778, indicating that considerable interconnection has already been established in that region. The high-voltage lines in other parts of the superpower zone are used mainly to transmit energy from sources where it is produced cheaply to points where it is used. The superpower system will multiply these sources of cheap production and will use the existing transmission lines as vehicles of distribution rather than of transmission. Accordingly, the present 33,000 to 66,000 volt transmission systems will be expanded for the distribution of the additional power made available by the superpower system.

CHARACTERISTICS OF THE SUPERPOWER TRANSMISSION SYSTEM.

The proposed transmission lines of the superpower system (see Pls. II, III, p. 14) are of two general classes—interconnecting lines between load centers, operating at 110,000 volts, and high-tension lines of large capacity, operating at 220,000 volts.

INTERCONNECTING LINES.

The interconnecting lines are to be used (1) to transfer energy from one load center to another in order to take care of small increments of growth in demand until additions to local generating plants are justified; (2) to provide means by which reserve capacity at centers of distribution in one part of the system may be made available for use in adjacent centers; (3) to equalize the load between the generating plants of the system or to distribute it among them as economy or policy may direct; (4) to transmit energy from power plants that are not at load centers and that are not provided with separate high-tension lines of transmission.

Any scheme for distributing load between generating centers over tie lines presupposes the automatic operation of governors on prime movers to maintain proper speed under all variations of load up to the full capacity of the generating units. An ideal interconnecting system would function automatically, for when an overload comes on any part of the system the prime mover of that part tends to slow down and lower the frequency, and its slowing down causes the generating units of the part affected to become somewhat out of phase with those of the rest of the system and produces a flow of energy from the lightly loaded to the more heavily loaded part of the system. Owing to physical and economic limitations, however, lines having considerable resistance and reactance can be automatically controlled only within rather narrow limits of load transfer between two load centers several miles apart, so that automatic regulation of voltage is not possible, except through a comparatively small range, without the use of special regulating equipment, for it presupposes a very low reactance circuit with relatively low resistance.

Under ordinary conditions energy may be transferred through a tie line so as to maintain the same bus voltage at all distributing points in a system by varying either the voltage or the impedance volts of the line. The voltage may be varied by shifting to different taps on the transformers, by the use of synchronous boosters, or by the use of some form of regulator. The induction regulator is probably the most satisfactory, and it should be manipulated by hand, as no device yet contrived can automatically distinguish between a variation due to a short circuit and one due to a change in demand. The impedance volts may be varied by the use of synchronous condensers at the receiving station.

In varying either the voltage or the impedance volts of the tie lines the limitations of synchronizing power and of corona effect should be considered. If a regulator is used a conductor of a size that will insure economy must be selected, and if synchronous condensers are used a design should be selected that will insure regulation rather than prevent loss of power.

If the tie lines are not long and if they are to carry relatively little energy the load can generally be carried by providing lines having low resistance. If the governors and the voltage regulators function properly they will automatically tend to distribute the energy as demanded if the fields in the generators in the station receiving energy are strengthened. If the demand is so great that the capacity to which the generator fields can be strengthened is exhausted before normal voltage is reached the deficiency must be supplied by providing synchronous-condenser capacity.

Consideration has been given to the effect of short circuits that may occur on the network of lines of the superpower system. Obviously, to insure the maximum economy an ideal system should be interconnected and operated as a unit. Studies of the possible concentration of energy resulting from short circuits at critical points in an ideal superpower system indicate, as was expected, that the short-circuit currents would exceed the rupturing capacity of any circuit breaker now available. In planning the interconnecting system contemplated in this report the limitations of the circuit breakers now available and the operating conditions to be provided for have been fully considered. If a short circuit occurs the system will be automatically separated at selected points into several systems that are complete in themselves, in order to limit the energy interrupted to amounts that can be readily handled. The feeders affected by the short circuit are thus automatically disconnected from the system, with minimum disturbance to the service. The rapid improvement in circuit breakers within the last few years leads us to expect that future improvement may produce apparatus that will permit much greater concentration of power, so that by the time the superpower system has grown to a size requiring circuit breakers of larger capacity they will probably be obtainable.

No insuperable difficulty is expected in obtaining rights of way for tie lines in the outlying districts of the superpower zone, where overhead circuits will be used, but rights of way in the congested parts of the large cities, where underground lines operated at comparatively low voltage are necessary, may not be obtained so easily. In New York City, for example, the generating stations are not now sufficiently provided with tie lines to insure the most economical operation on account of the prohibitive cost of conduits or conduit space for high-tension cables. Tie-line connection between New York and the industrial district of New Jersey is still more difficult to obtain and is even more necessary. Particular attention is called to the necessity of providing ample conduit space for tie lines in the new vehicular tunnel under the Hudson between New York and Jersey City.

TRANSMISSION LINES.

The principal elements to be considered in designing transmission lines are length of line, amount of energy to be transmitted, frequency, voltage, corona, resistance, reactance, conductance, susceptance, value of energy lost, cost of money, cost of operation, and value of energy delivered at the receiving end of the line. Kelvin's law is applicable here if the conductors are large enough to escape corona and if the investment in conductors includes the cost of other apparatus, which varies with the sizes of the conductors considered.

Length of line is determined by location of power plant with respect to market for power.

The amount of energy transmitted on a line may be limited either by the size of the generating plant or by the extent of the market. If a power plant is capable of an increase in capacity, the transmission line should have a margin of capacity to cover the increase or should be susceptible of additions at minimum cost.

The maximum practicable potential used for transmission to-day is 220,000 volts, and in the study of transmission to and within the superpower zone this and lower potentials are used.

Corona fixes one of the limits to economical long-distance transmission at very high voltages. There is a critical disruptive voltage for each size of cable, depending on spacing and arrangement of conductors, elevation above sea level, and meteorologic conditions. Rain, fog, and snow tend to lower the critical voltage. Up to 2,000 feet above sea level the minimum diameter of conductors for operation at 110,000 volts is about 0.45 inch and the minimum diameter of conductor for operation at 220,000 volts is about 0.95 inch.

The fundamental characteristics that determine the losses and the performance of a line are resistance, reactance, conductance, and susceptance. Resistance depends upon the size and length of the conductor and the material of which it is composed. Reactance varies with the frequency employed and with the length, size, arrangement, and spacing of the conductors. Conductance varies with the effect of corona and with insulation of line. Susceptance determines the charging current of the line and depends on the spacing, diameter, and arrangement of conductors, the frequency employed, and the length of circuit.

For lines of moderate length, say up to 350 miles, energy can be transmitted at 60 cycles, the prevailing frequency in the superpower zone. For longer lines it may be desirable to transmit at a lower frequency on account of the limitations of reactance and susceptance, but energy for use in the superpower zone will probably never be transmitted farther than 350 miles.

Kelvin's law is applicable to the design of high-tension transmission lines if account is taken of all the factors, which vary with variations in the conductors considered. The effect of these factors is subject to constant change, and the adoption of a particular design can be justified only if the cost of all the elements that may affect it are known. The cost of money, the cost of material, and the value of energy at the receiving end of the line are the principal elements involved.

The structural features of designs of existing transmission lines have been carefully worked out, and the designs for the transmission lines proposed involve no new problems. It may be economical, however, to use a type of tower construction for long lines that is different from the type used for comparatively short lines that transmit the same amounts of energy. For conductors of moderate size to be used under the usual limiting conditions the most economical tower spacing will be as follows: For hard-drawn copper, about 800 feet; for steel-reinforced copper, about 1,000 feet; for steel-reinforced aluminum cable, 1,200 to 1,500 feet.

The principal elements to be considered in spacing towers economically are (1) the character of the cable (weight, tensile strength, elastic limit, and temperature coefficient of linear expansion); (2) the clearance from the ground; (3) the assumed loading by ice and wind pressure; and (4) the cost of towers, foundations, insulators, and labor.

All 110,000 and 220,000 volt systems should be star connected with grounded neutral. The 110,000-volt lines may be provided with overhead ground wires where A-frame construction is used, but the 220,000-volt lines should not be provided with either ground wires or lightning arresters, for they will probably cause more trouble than they will prevent.

The entire superpower zone lies within an area that is occasionally subject to severe sleet storms, and authentic records show that sleet 1½ inches in radial thickness has been formed on line conductors. The cost of building transmission lines to withstand so heavy an accumulation of sleet would be prohibitive. The remedy is to keep the lines so warm during a sleet storm that ice will not collect on them, either by transmitting sufficient energy over them or by short-circuiting them and sending enough current through them at low voltage.

RIGHTS OF WAY.

The importance of adequate rights of way for transmission lines can hardly be overestimated. Many of the troubles on existing long-distance lines are due to crooked lines, which introduce hazardous construction. The service rendered to the public over many power lines is greater than the service rendered by some railroads, and these public lines should have rights of way commensurate with the value of their service. It is therefore an imperative public necessity that companies operating transmission systems should be granted rights of way through the exercise of the right of eminent domain. A 220,000-volt transmission system consisting of two tower lines, each containing two circuits, should have a right of way 240 feet wide and as straight as it can be made.

Transmission and tie lines should be so located as to avoid interference with service over communication circuits. In anticipation of the necessity of cooperation to avoid such interference conference was had with the engineers of the American Telephone & Telegraph Co., who have furnished the superpower survey a complete set of maps, consisting of 331 topographic sheets, fully indexed, showing the location of the toll lines of that company and its subsidiaries in the superpower zone. The preparation of these maps involved an enormous amount of work by the telephone company, and the set is too large for incorporation in this report, but it may be examined at the office of the United States Geological Survey at Washington.

PERFORMANCE OF TRANSMISSION LINES.

The performance of a transmission line may be determined graphically by the use of vector diagrams indicating currents and voltages at the ends of the circuit and applying the auxiliary constants of the circuit which account for the distribution effect. Figures 49–55 show the performance of a proposed transmission line from St. Lawrence River to a point in central New England. This line will be 225 miles long, will operate at 220,000 volts and 60 cycles, and has been designed to transmit 300,000 kilowatts and supply a distributing system that operates at a power factor of 85 per cent. The transmission system will consist of two tower lines, each supporting two circuits. The conductors are steel-reinforced aluminum cables measuring in cross section 605,000 circular mils and having a diameter of 0.953 inch. Each circuit will transmit 75,000 kilowatts under normal conditions and 150,000 kilowatts in an emergency. Additional data are given on the diagrams.

The diagrams show fully the graphic method of solution and also the mathematical solution. These solutions take into account the leakage and the local impedance of the raising and lowering transformers as well as the effect of these in reducing the effective synchronous-condenser capacity required under load. The mathematical solution given involves the values of the auxiliary constants determined by the employment of hyperbolic functions and is rigorously correct.

Figure 49 shows the conditions existing at no load, with normal load connections and with line and lowering transformers energized. With 220,000 volts at the receiving end of the line, measured at the low-voltage side of lowering transformers, a synchronous-reactor capacity of about 30,000 kilovolt-amperes will be required to hold the voltage at the sending end at 230,000 volts. A synchronous-reactor capacity of about 20,000 kilovolt-amperes will be required to maintain 220,000 volts at both the receiving and the sending ends of the line.

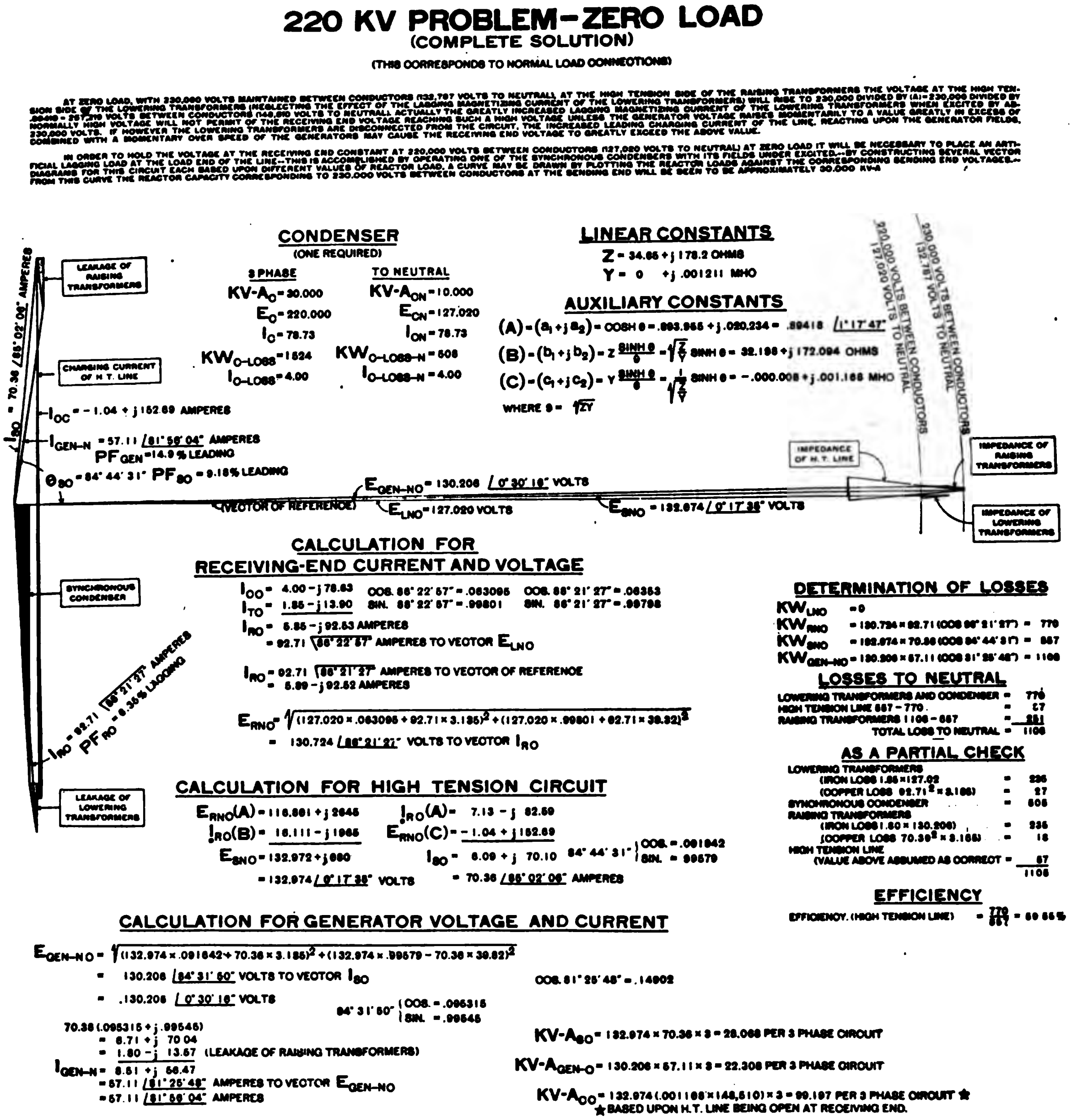
Figure 50 shows the performance of the system at a normal load of 75,000 kilowatts per circuit and 220,000 volts at the receiving end of the line. A synchronous-condenser capacity of about 42,000 kilovolt-amperes will be required to hold the receiving voltage at 220,000 volts with a load having a power factor of 85 per cent. If the voltage at the sending line is held at 220,000 volts the synchronous-condenser capacity required will be about 53,000 kilovolt-amperes.

Figure 51 shows the performance of the system with an emergency load of 150,000 kilowatts on each circuit, a condition that may exist for short intervals while one tower line is out of service for repair. Under these conditions a condenser capacity of 173,000 kilovolt-amperes will be required to hold voltage constant at 220,000 volts at both ends of the line.

Figure 52 shows the amount of energy that may be delivered over this line under various conditions of sending-end voltage to an 85 per cent power-factor load, with 220,000 volts at the receiving end.

Figure 53 shows the synchronous-condenser capacity required for various loads at the three sending-end voltages that are most likely to be used.

Figure 54 shows the voltage on each side of the raising transformers corresponding to condenser loads of various capacities in parallel with a load of 75,000 kilowatts at a power factor of 85 per cent. The vertical distance between the two voltage lines is the voltage drop or voltage rise through the raising transformers. For condenser loads up to 15,000 kilovolt-amperes there is a drop in voltage through the raising transformers. For condenser loads above 15,000 kilovolt-amperes there is a rise in voltage through the raising transformers.



220 KV PROBLEM–ZERO LOAD
(COMPLETE SOLUTION)
(THIS CORRESPONDS TO NORMAL LOAD CONNECTIONS)

AT ZERO LOAD, WITH 230,000 VOLTS MAINTAINED BETWEEN CONDUCTORS (132,787 VOLTS TO NEUTRAL), AT THE HIGH TENSION SIDE OF THE RAISING TRANSFORMERS THE VOLTAGE AT THE HIGH TENSION SIDE OF THE LOWERING TRANSFORMERS (NEGLECTING THE EFFECT OF THE LAGGING MAGNETIZING CURRENT OF THE LOWERING TRANSFORMERS) WILL RISE TO 230,000 DIVIDED BY (A) = 230,000 DIVIDED BY .89418 = 257,219 VOLTS BETWEEN CONDUCTORS (148,510 VOLTS TO NEUTRAL). ACTUALLY THE GREATLY INCREASED LAGGING MAGNETIZING CURRENT OF THE LOWERING TRANSFORMERS WHEN EXCITED BY ABNORMALLY HIGH VOLTAGE WILL NOT PERMIT OF THE RECEIVING END VOLTAGE REACHING SUCH A HIGH VOLTAGE UNLESS THE GENERATOR VOLTAGE RAISES MOMENTARILY TO A VALUE GREATLY IN EXCESS OF 230,000 VOLTS. IF HOWEVER THE LOWERING TRANSFORMERS ARE DISCONNECTED FROM THE CIRCUIT, THE INCREASED LEADING CHARGING CURRENT OF THE LINE, REACTING UPON THE GENERATOR FIELDS, COMBINED WITH A MOMENTARY OVER SPEED OF THE GENERATORS MAY CAUSE THE RECEIVING END VOLTAGE TO GREATLY EXCEED THE ABOVE VALUE.

IN ORDER TO HOLD THE VOLTAGE AT THE RECEIVING END CONSTANT AT 220,000 VOLTS BETWEEN CONDUCTORS (127,020 VOLTS TO NEUTRAL) AT ZERO LOAD IT WILL BE NECESSARY TO PLACE AN ARTIFICIAL LAGGING LOAD AT THE LOAD END OF THE LINE--THIS IS ACCOMPLISHED BY OPERATING ONE OF THE SYNCHRONOUS CONDENSERS WITH ITS FIELDS UNDER EXCITED.--BY CONSTRUCTING SEVERAL VECTOR DIAGRAMS FOR THIS CIRCUIT EACH BASED UPON DIFFERENT VALUES OF REACTOR LOAD, A CURVE MAY BE DRAWN BY PLOTTING THE REACTOR LOADS AGAINST THE CORRESPONDING SENDING END VOLTAGES.--FROM THIS CURVE THE REACTOR CAPACITY CORRESPONDING TO 230,000 VOLTS BETWEEN CONDUCTORS AT THE SENDING END WILL BE SEEN TO BE APPROXIMATELY 30,000 KV-A

CONDENSER
(ONE REQUIRED)
3 PHASE
$KV\text{-}A_O = 30.000$
$E_O = 220.000$
$I_O = 78.73$
$KW_{O\text{-}LOSS} = 1524$
$I_{O\text{-}LOSS} = 4.00$
TO NEUTRAL
$KV\text{-}A_{ON} = 10.000$
$E_{CN} = 127.020$
$I_{ON} = 78.73$
$KW_{O\text{-}LOSS\text{-}N} = 508$
$I_{O\text{-}LOSS\text{-}N} = 4.00$
LINEAR CONSTANTS
Z = 34.65 + j 178.2 OHMS
Y = 0 + j .001211 MHO
AUXILIARY CONSTANTS
(A) = (a₁ + j a₂) = COSH θ = .893.965 + j .020.234 = .89418 /1° 17′ 47″
(B) = (b₁ + j b₂) = Z SINH θ / θ = √(Z/Y) SINH θ = 32.198 + j 172.094 OHMS
(C) = (c₁ + j c₂) = Y SINH θ / θ = 1/√(Z/Y) SINH θ = −.000.008 + j .001.168 MHO
WHERE θ = √ZY
220,000 VOLTS BETWEEN CONDUCTORS
127,020 VOLTS TO NEUTRAL
230,000 VOLTS BETWEEN CONDUCTORS
132,787 VOLTS TO NEUTRAL
LEAKAGE OF RAISING TRANSFORMERS
CHARGING CURRENT OF H. T. LINE
SYNCHRONOUS CONDENSER
LEAKAGE OF LOWERING TRANSFORMERS
IMPEDANCE OF H. T. LINE
IMPEDANCE OF RAISING TRANSFORMERS
IMPEDANCE OF LOWERING TRANSFORMERS
I_SO = 70.36 /85° 02′ 06″ AMPERES
I_OC = −1.04 + j 152.69 AMPERES
I_GEN-N = 57.11 /81° 56′ 04″ AMPERES
PF_GEN = 14.9 % LEADING
θ_SO = 84° 44′ 31″ PF_SO = 9.18% LEADING
E_GEN-NO = 130.206 /0° 30′ 16″ VOLTS
(VECTOR OF REFERENCE)
E_LNO = 127.020 VOLTS
E_SNO = 132.974 /0° 17′ 38″ VOLTS
I_RO = 92.71 /88° 21′ 27″ AMPERES
PF_RO = 6.36% LAGGING
CALCULATION FOR RECEIVING-END CURRENT AND VOLTAGE
I_OO = 4.00 − j 78.63   COS. 86° 22′ 57″ = .063095   COS. 86° 21′ 27″ = .06353
I_TO = 1.85 − j 13.90   SIN. 86° 22′ 57″ = .99801   SIN. 86° 21′ 27″ = .99798
I_RO = 5.85 − j 92.53 AMPERES
= 92.71 /86° 22′ 57″ AMPERES TO VECTOR E_LNO
I_RO = 92.71 /86° 21′ 27″ AMPERES TO VECTOR OF REFERENCE
= 5.89 − j 92.52 AMPERES
E_RNO = √((127.020 × .063095 + 92.71 × 3.185)² + (127.020 × .99801 + 92.71 × 38.32)²)
= 130.724 /86° 21′ 27″ VOLTS TO VECTOR I_RO
CALCULATION FOR HIGH TENSION CIRCUIT
E_RNO(A) = 116.881 + j 2845
I_RO(A) = 7.13 − j 82.59
I_RO(B) = 16.111 − j 1965
E_RNO(C) = −1.04 + j 152.69
E_SNO = 132.972 + j 680
I_SO = 6.09 + j 70.10   84° 44′ 31″ COS. = .091642 SIN. = .99579
= 132.974 /0° 17′ 38″ VOLTS
= 70.36 /85° 02′ 06″ AMPERES
CALCULATION FOR GENERATOR VOLTAGE AND CURRENT
E_GEN-NO = √((132.974 × .091642 + 70.36 × 3.185)² + (132.974 × .99579 − 70.36 × 38.82)²)
= 130.206 /84° 31′ 50″ VOLTS TO VECTOR I_SO
= 130.206 /0° 30′ 16″ VOLTS
84° 31′ 50″ COS. = .095315 SIN. = .99545
COS. 81° 25′ 48″ = .14902
70.36 (.095315 + j .99545)
= 6.71 + j 70.04
= 1.80 − j 13.57 (LEAKAGE OF RAISING TRANSFORMERS)
I_GEN-N = 8.51 + j 56.47
= 57.11 /81° 25′ 48″ AMPERES TO VECTOR E_GEN-NO
= 57.11 /81° 56′ 04″ AMPERES
KV-A_SO = 132.974 × 70.36 × 3 = 28.068 PER 3 PHASE CIRCUIT
KV-A_GEN-O = 130.206 × 57.11 × 3 = 22.308 PER 3 PHASE CIRCUIT
KV-A_OO = 132.974 (.001168 × 148,510) × 3 = 69.197 PER 3 PHASE CIRCUIT ★
★ BASED UPON H. T. LINE BEING OPEN AT RECEIVING END.
DETERMINATION OF LOSSES
KW_LNO = 0
KW_RNO = 130.724 × 92.71 (COS 86° 21′ 27″) = 770
KW_SNO = 132.974 × 70.36 (COS 84° 44′ 31″) = 857
KW_GEN-NO = 130.206 × 57.11 (COS 81° 25′ 48″) = 1106
LOSSES TO NEUTRAL
LOWERING TRANSFORMERS AND CONDENSER = 770
HIGH TENSION LINE 857 − 770 = 87
RAISING TRANSFORMERS 1106 − 857 = 251
TOTAL LOSS TO NEUTRAL = 1106
AS A PARTIAL CHECK
LOWERING TRANSFORMERS
(IRON LOSS 1.85 × 127.02 = 235
(COPPER LOSS 92.71² × 3.185) = 27
SYNCHRONOUS CONDENSER = 508
RAISING TRANSFORMERS
(IRON LOSS 1.80 × 130.206) = 235
(COPPER LOSS 70.36² × 3.185) = 16
HIGH TENSION LINE
(VALUE ABOVE ASSUMED AS CORRECT = 87
1106
EFFICIENCY
EFFICIENCY (HIGH TENSION LINE) = 770/857 = 89.85%

FIGURE 49.—Vector diagram for 225-mile transmission line with no load.

Figure 55 is a general diagram showing a possible arrangement of generating, transforming, and transmitting equipment for the St. Lawrence-New England project.

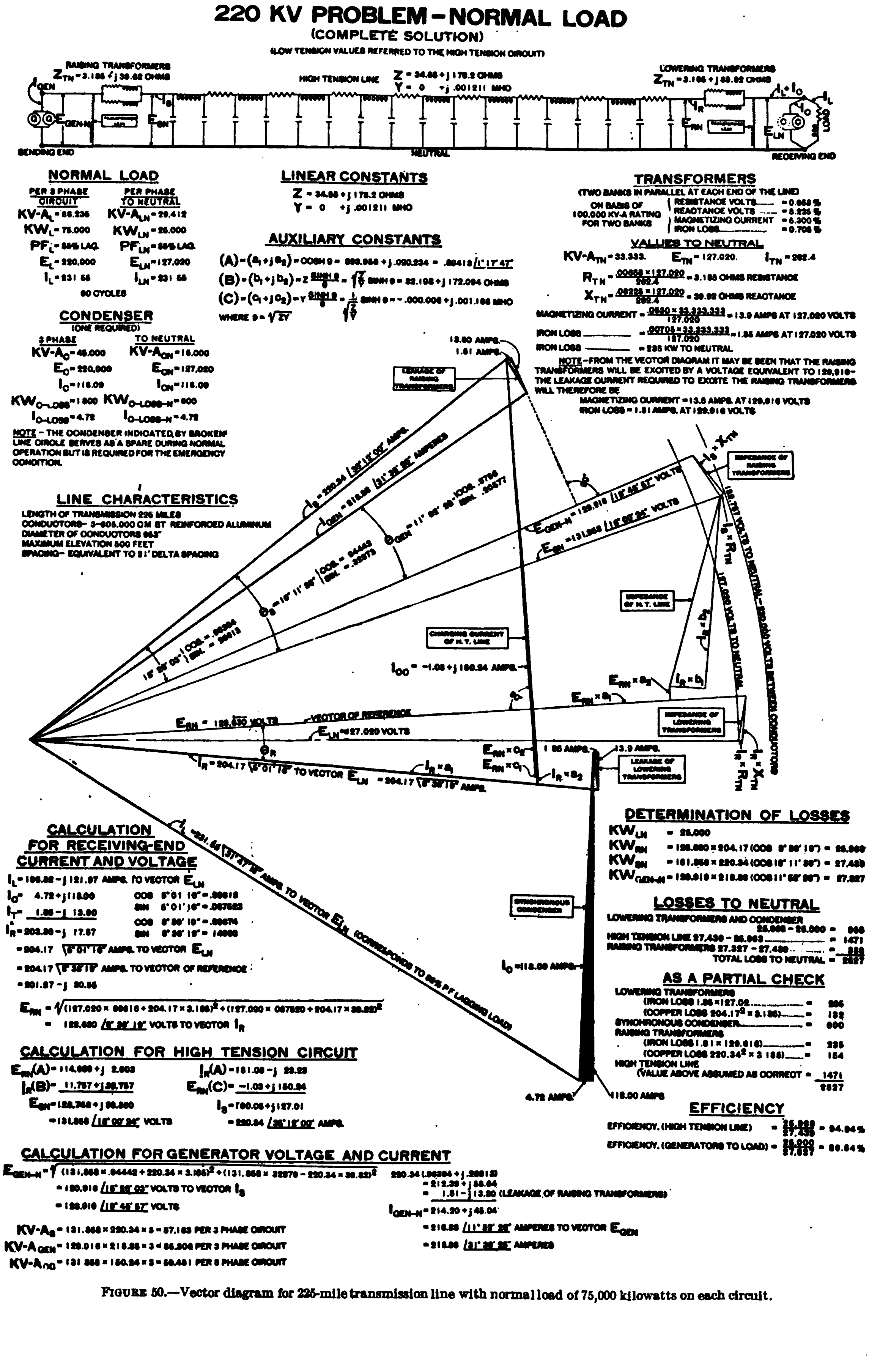
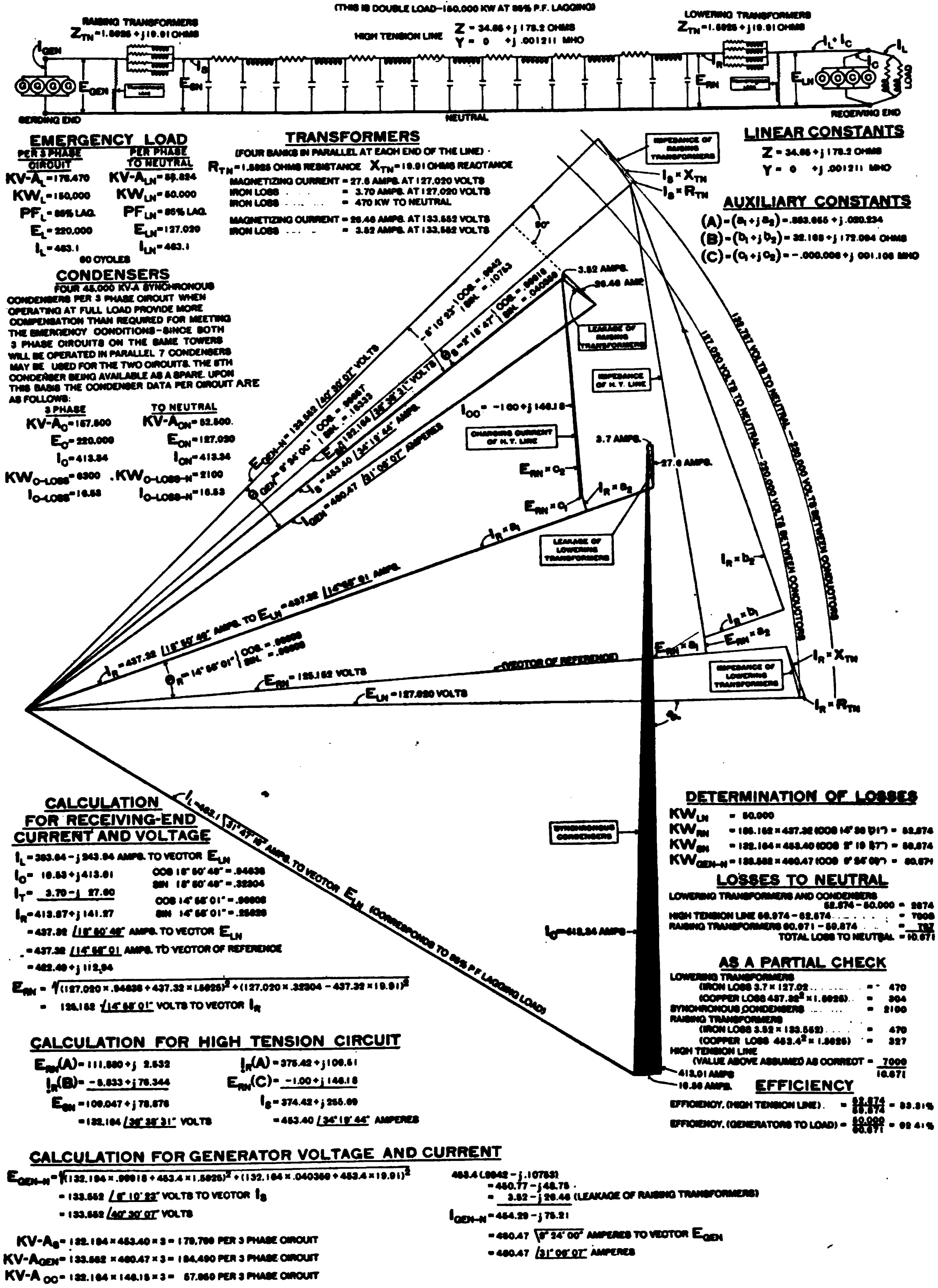

220 KV PROBLEM - NORMAL LOAD
(COMPLETE SOLUTION)
(LOW TENSION VALUES REFERRED TO THE HIGH TENSION CIRCUIT)
RAISING TRANSFORMERS
Z_TN = 3.186 + j 39.82 OHMS
HIGH TENSION LINE
Z = 34.88 + j 178.2 OHMS
Y = 0 + j .001211 MHO
LOWERING TRANSFORMERS
Z_TN = 3.186 + j 39.82 OHMS
I_GEN
E_GEN-N
E_SN
I_S
I_R
E_RN
E_LN
I_L + I_O
I_O
I_L
LOAD
SENDING END
NEUTRAL
RECEIVING END
NORMAL LOAD
PER 3 PHASE CIRCUIT
PER PHASE TO NEUTRAL
KV-A_L = 88.236
KV-A_LN = 29.412
KW_L = 75.000
KW_LN = 25.000
PF_L = 85% LAG
PF_LN = 85% LAG
E_L = 220.000
E_LN = 127.020
I_L = 231 56
I_LN = 231 56
60 CYCLES
LINEAR CONSTANTS
Z = 34.88 + j 178.2 OHMS
Y = 0 + j .001211 MHO
AUXILIARY CONSTANTS
(A) = (a1 + j a2) = COSH θ = .893.956 + j .020.234 = .89418 /1° 17' 47"
(B) = (b1 + j b2) = Z SINH θ / θ = √(Z/Y) SINH θ = 32.198 + j 172.094 OHMS
(C) = (c1 + j c2) = Y SINH θ / θ = 1/√(Z/Y) SINH θ = -.000.008 + j .001.186 MHO
WHERE θ = √ZY
CONDENSER
(ONE REQUIRED)
3 PHASE
TO NEUTRAL
KV-A_C = 45.000
KV-A_CN = 15.000
E_C = 220.000
E_CN = 127.020
I_C = 118.09
I_CN = 118.09
KW_C-LOSS = 1800
KW_C-LOSS-N = 600
I_C-LOSS = 4.72
I_C-LOSS-N = 4.72
NOTE - THE CONDENSER INDICATED BY BROKEN LINE CIRCLE SERVES AS A SPARE DURING NORMAL OPERATION BUT IS REQUIRED FOR THE EMERGENCY CONDITION.
TRANSFORMERS
(TWO BANKS IN PARALLEL AT EACH END OF THE LINE)
ON BASIS OF 100.000 KV-A RATING FOR TWO BANKS
RESISTANCE VOLTS = 0.658 %
REACTANCE VOLTS = 8.225 %
MAGNETIZING CURRENT = 5.300 %
IRON LOSS = 0.706 %
VALUES TO NEUTRAL
KV-A_TN = 33.333.
E_TN = 127.020.
I_TN = 262.4
R_TN = .00658 × 127.020 / 262.4 = 3.186 OHMS RESISTANCE
X_TN = .08225 × 127.020 / 262.4 = 39.82 OHMS REACTANCE
MAGNETIZING CURRENT = .0530 × 33.333.333 / 127.020 = 13.9 AMPS AT 127.020 VOLTS
IRON LOSS = .00706 × 33.333.333 / 127.020 = 1.85 AMPS AT 127.020 VOLTS
IRON LOSS = 235 KW TO NEUTRAL
NOTE - FROM THE VECTOR DIAGRAM IT MAY BE SEEN THAT THE RAISING TRANSFORMERS WILL BE EXCITED BY A VOLTAGE EQUIVALENT TO 129.916 - THE LEAKAGE CURRENT REQUIRED TO EXCITE THE RAISING TRANSFORMERS WILL THEREFORE BE
MAGNETIZING CURRENT = 13.8 AMPS. AT 129.916 VOLTS
IRON LOSS = 1.81 AMPS. AT 129.916 VOLTS
LINE CHARACTERISTICS
LENGTH OF TRANSMISSION 225 MILES
CONDUCTORS - 3-605.000 CM ST REINFORCED ALUMINUM
DIAMETER OF CONDUCTORS .953"
MAXIMUM ELEVATION 500 FEET
SPACING - EQUIVALENT TO 21' DELTA SPACING
13.80 AMPS.
1.81 AMPS.
LEAKAGE OF RAISING TRANSFORMERS
I_S = 220.34 /35° 12' 00" AMPS.
I_GEN = 218.88 /31° 25' 25" AMPERES
θ_GEN = 11° 55' 35" (COS. .9785 / SIN. .20577)
θ_S = 16° 11' 35" (COS. .94445 / SIN. .32872)
15° 26' 03" (COS. .96394 / SIN. .26613)
E_GEN-N = 129.916 /15° 45' 57" VOLTS
E_SN = 131.868 /15° 00' 24" VOLTS
I_S × X_TN
IMPEDANCE OF RAISING TRANSFORMERS
I_S × R_TN
129.757 VOLTS TO NEUTRAL - 220.000 VOLTS BETWEEN CONDUCTORS
127.020 VOLTS TO NEUTRAL
IMPEDANCE OF H.T. LINE
I_R × b2
I_R × b1
E_RN × a2
E_RN × a1
CHARGING CURRENT OF H.T. LINE
I_OO = -1.03 + j 150.34 AMPS.
E_RN = 128.630 VOLTS
VECTOR OF REFERENCE
E_LN = 127.020 VOLTS
θ_R
IMPEDANCE OF LOWERING TRANSFORMERS
I_R = 204.17 \5° 01' 16" TO VECTOR E_LN = 204.17 \8° 38' 18" AMPS.
I_R × a1
E_RN × c2
E_RN × c1
I_R × a2
1.85 AMPS.
13.9 AMPS.
LEAKAGE OF LOWERING TRANSFORMERS
I_R × R_TN
I_R × X_TN
I_L = 231.56 \31° 47' 18" AMPS TO VECTOR E_LN (CORRESPONDS TO 85% PF LAGGING LOAD)
SYNCHRONOUS CONDENSER
I_O = 118.00 AMPS.
4.72 AMPS.
118.00 AMPS
CALCULATION FOR RECEIVING-END CURRENT AND VOLTAGE
I_L = 196.82 - j 121.97 AMPS. TO VECTOR E_LN
I_O = 4.72 + j 118.00
I_T = 1.85 - j 13.90
I_R = 203.39 - j 17.87
COS 5° 01' 16" = .99616
SIN 5° 01' 16" = .087523
COS 8° 38' 19" = .98874
SIN 8° 38' 19" = .14966
= 204.17 \5° 01' 16" AMPS. TO VECTOR E_LN
= 204.17 \8° 38' 18" AMPS. TO VECTOR OF REFERENCE
= 201.87 - j 30.56
E_RN = √((127.020 × .99616 + 204.17 × 3.186)² + (127.020 × .087520 + 204.17 × 39.82)²)
= 128.630 /8° 36' 19" VOLTS TO VECTOR I_R
CALCULATION FOR HIGH TENSION CIRCUIT
E_RN(A) = 114.989 + j 2.603
I_R(B) = 11.757 + j 36.757
E_SN = 126.746 + j 39.360
= 131.868 /15° 00' 24" VOLTS
I_R(A) = 181.08 - j 23.23
E_RN(C) = -1.03 + j 150.24
I_S = 180.05 + j 127.01
= 220.34 /35° 12' 00" AMPS.
CALCULATION FOR GENERATOR VOLTAGE AND CURRENT
E_GEN-N = √((131.868 × .94442 + 220.34 × 3.186)² + (131.868 × .32870 - 220.34 × 39.82)²)
= 129.916 /15° 26' 03" VOLTS TO VECTOR I_S
= 129.916 /15° 45' 57" VOLTS
220.34 (.96394 + j .26613)
= 212.39 + j 58.64
= 1.81 - j 13.80 (LEAKAGE OF RAISING TRANSFORMERS)
I_GEN-N = 214.20 + j 45.04
= 218.88 /11° 55' 35" AMPERES TO VECTOR E_GEN
= 218.88 /31° 25' 25" AMPERES
KV-A_S = 131.868 × 220.34 × 3 = 87.163 PER 3 PHASE CIRCUIT
KV-A_GEN = 129.916 × 218.88 × 3 = 85.308 PER 3 PHASE CIRCUIT
KV-A_OO = 131 868 × 150.24 × 3 = 59.481 PER 3 PHASE CIRCUIT
DETERMINATION OF LOSSES
KW_LN = 25.000
KW_RN = 128.630 × 204.17 (COS 8° 36' 19") = 25.968
KW_SN = 131.868 × 220.34 (COS 18° 11' 36") = 27.439
KW_GEN-N = 129.916 × 218.88 (COS 11° 55' 35") = 27.827
LOSSES TO NEUTRAL
LOWERING TRANSFORMERS AND CONDENSER 25.968 - 25.000 = 968
HIGH TENSION LINE 27.439 - 25.968 = 1471
RAISING TRANSFORMERS 27.827 - 27.439 = 388
TOTAL LOSS TO NEUTRAL = 2827
AS A PARTIAL CHECK
LOWERING TRANSFORMERS
(IRON LOSS 1.85 × 127.02 = 235
(COPPER LOSS 204.17² × 3.186) = 132
SYNCHRONOUS CONDENSER = 600
RAISING TRANSFORMERS
(IRON LOSS 1.81 × 129.916) = 235
(COPPER LOSS 220.34² × 3 186) = 154
HIGH TENSION LINE
(VALUE ABOVE ASSUMED AS CORRECT = 1471
2827
EFFICIENCY
EFFICIENCY. (HIGH TENSION LINE) = 25.968 / 27.439 = 94.64 %
EFFICIENCY. (GENERATORS TO LOAD) = 25.000 / 27.827 = 89.84 %

FIGURE 50.—Vector diagram for 225-mile transmission line with normal load of 75,000 kilowatts on each circuit.

220 KV PROBLEM – EMERGENCY LOAD

(COMPLETE SOLUTION)

(THIS IS DOUBLE LOAD–150,000 KW AT 85% P.F. LAGGING)


RAISING TRANSFORMERS
Z_{TN} = 1.5925 + j 19.91 OHMS
HIGH TENSION LINE
Z = 34.66 + j 178.2 OHMS
Y = 0 + j .001211 MHO
LOWERING TRANSFORMERS
Z_{TN} = 1.5925 + j 19.91 OHMS
I_{GEN}
E_{GEN}
I_S
E_{SN}
I_R
E_{RN}
E_{LN}
$I_L + I_C$
I_L
I_C
LOAD
SENDING END
NEUTRAL
RECEIVING END
IMPEDANCE OF RAISING TRANSFORMERS
$I_S \times X_{TN}$
$I_S \times R_{TN}$
90°
3.52 AMPS.
26.46 AMP.
LEAKAGE OF RAISING TRANSFORMERS
IMPEDANCE OF H. T. LINE
I_{OO} = −1.00 + j 146.18
CHARGING CURRENT OF H. T. LINE
3.7 AMPS.
27.6 AMPS.
$E_{RN} \times c_2$
$E_{RN} \times c_1$
$I_R \times a_2$
$I_R \times a_1$
LEAKAGE OF LOWERING TRANSFORMERS
$I_R \times b_2$
$I_R \times b_1$
$E_{RN} \times a_1$
$E_{RN} \times a_2$
$I_R \times X_{TN}$
$I_R \times R_{TN}$
IMPEDANCE OF LOWERING TRANSFORMERS
133.737 VOLTS TO NEUTRAL – 230,000 VOLTS BETWEEN CONDUCTORS
127.020 VOLTS TO NEUTRAL – 220,000 VOLTS BETWEEN CONDUCTORS
E_{GEN-N} = 133.552 /40° 30′ 07″ VOLTS
θ_{GEN} = 8° 24′ 00″ | COS. = .98927 | SIN. = .14333
$-8°$ 10′ 23″ | COS. = .9942 | SIN. = .10753
E_{SN} = 132.164 /36° 38′ 31″ VOLTS
θ_S = 2° 18′ 47″ | COS. = .99918 | SIN. = .040358
I_S = 453.40 /34° 19′ 44″ AMPS.
I_{GEN} = 460.47 /31° 06′ 07″ AMPERES
I_R = 437.32 /15° 50′ 46″ AMPS. TO E_{LN} = 437.32 /15° 55′ 01 AMPS.
θ_R = 14° 56′ 01″ | COS. = .96606 | SIN. = .25809
E_{RN} = 125.152 VOLTS
VECTOR OF REFERENCE
E_{LN} = 127.020 VOLTS
θ_L
I_L = 463.1 /31° 47′ 15″ AMPS. TO VECTOR E_{LN} (CORRESPONDS TO 85% P.F. LAGGING LOAD)
SYNCHRONOUS CONDENSERS
I_O = 413.34 AMPS.
413.01 AMPS
16.36 AMPS.

EMERGENCY LOAD

PER 3 PHASE CIRCUIT	PER PHASE TO NEUTRAL
$KV\text{-}A_L$ = 176.470	$KV\text{-}A_{LN}$ = 58.824
KW_L = 150,000	KW_{LN} = 50.000
PF_L = 85% LAG.	PF_{LN} = 85% LAG.
E_L = 220.000	E_{LN} = 127.020
I_L = 463.1	I_{LN} = 463.1

60 CYCLES

TRANSFORMERS

(FOUR BANKS IN PARALLEL AT EACH END OF THE LINE)

R_{TN} = 1.5925 OHMS RESISTANCE X_{TN} = 19.91 OHMS REACTANCE

MAGNETIZING CURRENT = 27.6 AMPS. AT 127.020 VOLTS
IRON LOSS . . . . = 3.70 AMPS. AT 127.020 VOLTS
IRON LOSS . . . . = 470 KW TO NEUTRAL

MAGNETIZING CURRENT = 26.46 AMPS. AT 133.552 VOLTS
IRON LOSS . . . . = 3.52 AMPS. AT 133.552 VOLTS

LINEAR CONSTANTS

Z = 34.66 + j 178.2 OHMS
Y = 0 + j .001211 MHO

AUXILIARY CONSTANTS

$(A) = (a_1 + j a_2)$ = .983.655 + j .020.234
$(B) = (b_1 + j b_2)$ = 32.168 + j 172.094 OHMS
$(C) = (c_1 + j c_2)$ = −.000.006 + j 001.106 MHO

CONDENSERS

FOUR 45,000 KV-A SYNCHRONOUS CONDENSERS PER 3 PHASE CIRCUIT WHEN OPERATING AT FULL LOAD PROVIDE MORE COMPENSATION THAN REQUIRED FOR MEETING THE EMERGENCY CONDITIONS–SINCE BOTH 3 PHASE CIRCUITS ON THE SAME TOWERS WILL BE OPERATED IN PARALLEL 7 CONDENSERS MAY BE USED FOR THE TWO CIRCUITS. THE 8TH CONDENSER BEING AVAILABLE AS A SPARE. UPON THIS BASIS THE CONDENSER DATA PER CIRCUIT ARE AS FOLLOWS:

3 PHASE	TO NEUTRAL
$KV\text{-}A_O$ = 157.500	$KV\text{-}A_{ON}$ = 52.500.
E_O = 220.000	E_{ON} = 127.020
I_O = 413.34	I_{ON} = 413.34
$KW_{O\text{-}LOSS}$ = 6300	$KW_{O\text{-}LOSS\text{-}N}$ = 2100
$I_{O\text{-}LOSS}$ = 16.53	$I_{O\text{-}LOSS\text{-}N}$ = 16.53

CALCULATION FOR RECEIVING-END CURRENT AND VOLTAGE

I_L = 393.64 − j 243.94 AMPS. TO VECTOR E_{LN}
I_O = 16.53 + j 413.01
I_T = 3.70 − j 27.60
I_R = 413.87 + j 141.27
= 437.32 /15° 50′ 46″ AMPS. TO VECTOR E_{LN}
= 437.32 /14° 56′ 01 AMPS. TO VECTOR OF REFERENCE
= 422.49 + j 112.94

COS 18° 50′ 46″ = .94636
SIN 18° 50′ 46″ = .32304
COS 14° 56′ 01″ = .96606
SIN 14° 56′ 01″ = .25826

$E_{RN} = \sqrt{(127.020 \times .94636 + 437.32 \times 1.5925)^2 + (127.020 \times .32304 - 437.32 \times 19.91)^2}$
= 125.152 /14° 56′ 01″ VOLTS TO VECTOR I_R

CALCULATION FOR HIGH TENSION CIRCUIT

$E_{RN}(A)$ = 111.880 + j 2.532
$I_R(B)$ = −5.833 + j 76.344
E_{SN} = 106.047 + j 78.876
= 132.164 /36° 38′ 31″ VOLTS

$I_R(A)$ = 375.42 + j 109.51
$E_{RN}(C)$ = −1.00 + j 146.18
I_S = 374.42 + j 255.69
= 453.40 /34° 19′ 44″ AMPERES

CALCULATION FOR GENERATOR VOLTAGE AND CURRENT

$E_{GEN-N} = \sqrt{(132.164 \times .99918 + 453.4 \times 1.5925)^2 + (132.164 \times .040358 + 453.4 \times 19.91)^2}$
= 133.552 /8° 10′ 23″ VOLTS TO VECTOR I_S
= 133.552 /40° 30′ 07″ VOLTS

453.4 (.9942 − j .10753)
= 450.77 − j 48.75
= 3.52 − j 26.46 (LEAKAGE OF RAISING TRANSFORMERS)
I_{GEN-N} = 454.29 − j 75.21
= 460.47 /8° 24′ 00″ AMPERES TO VECTOR E_{GEN}
= 460.47 /31° 06′ 07″ AMPERES

$KV\text{-}A_S$ = 132.164 × 453.40 × 3 = 179.769 PER 3 PHASE CIRCUIT
$KV\text{-}A_{GEN}$ = 133.552 × 460.47 × 3 = 184.490 PER 3 PHASE CIRCUIT
$KV\text{-}A_{OO}$ = 132.164 × 146.18 × 3 = 57.960 PER 3 PHASE CIRCUIT

DETERMINATION OF LOSSES

KW_{LN} = 50.000
KW_{RN} = 125.152 × 437.32 (COS 14° 56′ 01″) = 52.874
KW_{SN} = 132.164 × 453.40 (COS 2° 18′ 47″) = 59.874
KW_{GEN-N} = 133.552 × 460.47 (COS 8° 24′ 00″) = 60.671

LOSSES TO NEUTRAL

LOWERING TRANSFORMERS AND CONDENSERS
52.874 − 50.000 = 2874
HIGH TENSION LINE 59.874 − 52.874 . . . . = 7000
RAISING TRANSFORMERS 60.671 − 59.874 . . . = 797
TOTAL LOSS TO NEUTRAL = 10.671

AS A PARTIAL CHECK

LOWERING TRANSFORMERS
(IRON LOSS 3.7 × 127.02 . . . . = 470
(COPPER LOSS 437.32^2 × 1.5925) . . = 304
SYNCHRONOUS CONDENSERS . . . . = 2100
RAISING TRANSFORMERS
(IRON LOSS 3.52 × 133.552) . . . . = 470
(COPPER LOSS 453.4^2 × 1.5925) = 327
HIGH TENSION LINE
(VALUE ABOVE ASSUMED AS CORRECT = 7000
10.671

EFFICIENCY

EFFICIENCY, (HIGH TENSION LINE) . = $\frac{52.874}{59.874}$ = 88.31%
EFFICIENCY, (GENERATORS TO LOAD) = $\frac{50.000}{60.671}$ = 82.41%

FIGURE 51.—Vector diagram for 225-mile transmission line with emergency load of 150,000 kilowatts on each circuit.

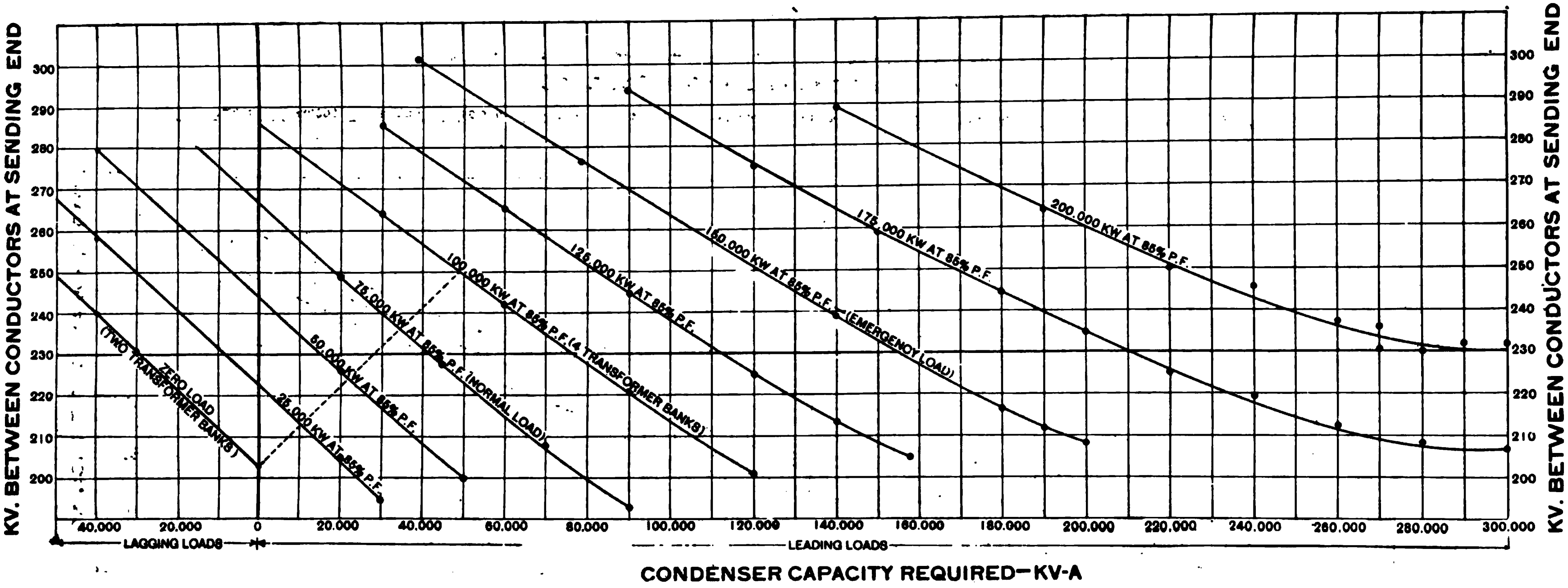


FIGURE 52.—Energy delivered over 225-mile transmission line.

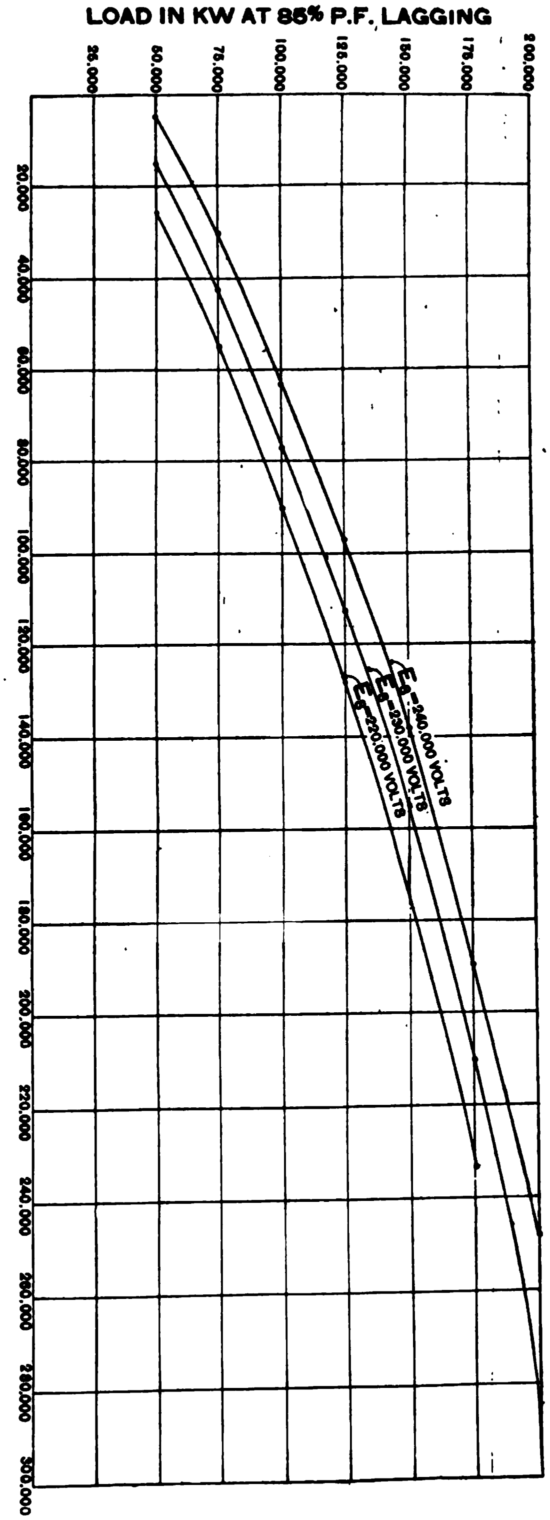


FIGURE 53.—Synchronous-condenser capacity required for 225-mile transmission line.

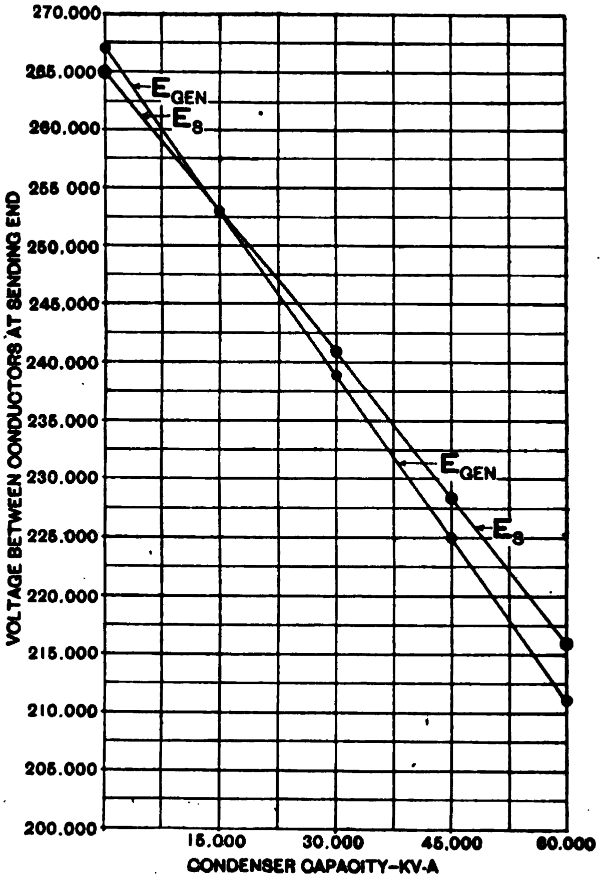
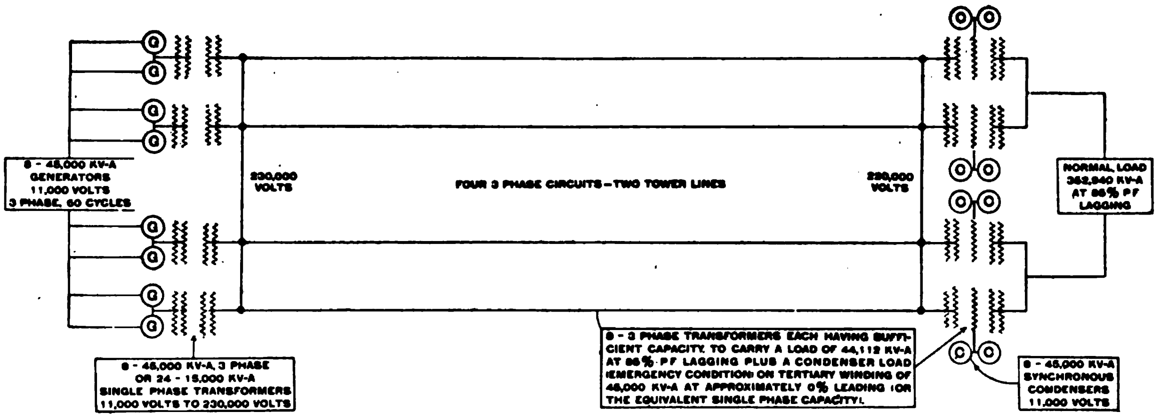


FIGURE 54.—Voltage on raising transformers for 225-mile transmission line.


8 - 45,000 KV-A GENERATORS 11,000 VOLTS 3 PHASE, 60 CYCLES
230,000 VOLTS
FOUR 3 PHASE CIRCUITS—TWO TOWER LINES
220,000 VOLTS
NORMAL LOAD 352,940 KV-A AT 85% PF LAGGING
8 - 45,000 KV-A, 3 PHASE OR 24 - 15,000 KV-A SINGLE PHASE TRANSFORMERS 11,000 VOLTS TO 230,000 VOLTS
8 - 3 PHASE TRANSFORMERS EACH HAVING SUFFICIENT CAPACITY TO CARRY A LOAD OF 44,112 KV-A AT 85% PF LAGGING PLUS A CONDENSER LOAD (EMERGENCY CONDITION) ON TERTIARY WINDING OF 45,000 KV-A AT APPROXIMATELY 0% LEADING (OR THE EQUIVALENT SINGLE PHASE CAPACITY).
8 - 45,000 KV-A SYNCHRONOUS CONDENSERS 11,000 VOLTS

NOTE— SWITCHING EQUIPMENT PERMITS OF THE ENTIRE LOAD BEING TRANSMITTED OVER ONE TOWER LINE (TWO CIRCUITS)

FIGURE 55.—Possible arrangement of equipment for St. Lawrence-New England project.

TABLE 94.—*Character and performance of lines that have been considered as sources of energy for the superpower zone.*

	Niagara Falls-New York line.	St. Lawrence-New England line.	Pittston-Newark line.
Character.			
Energy to be transmitted...kilowatts..	300,000	300,000	300,000
Length of line...miles..	350	225	115
Voltage at generating end...	220,000	220,000	230,000
Voltage at receiving end...	220,000	200,000	200,000
Frequency...cycles..	60	60	60
Number of tower lines...	2	2	2
Number of circuits per tower line...	2	2	1
Size of conductor:			
Aluminum...circular mils..	605,000	....	920,000
Steel...do....	78,000	....	271,000
Copper...do....	....	640,000	....
Normal load per circuit...kilowatts..	75,000	75,000	150,000
Emergency load per circuit...do....	150,000	150,000	300,000
Power factor of load (lagging)...per cent..	85	85	85
Performance under normal load.			
Power factor at sending end of line (leading)...per cent..	88.1	99.5	94.7
Power factor at receiving end of line (lagging)...do....	98.8	96.1	97.6
Synchronous-condenser capacity required...kilovolt-amperes..	180,000	140,000	160,000
Line losses...kilowatts..	28,500	12,500	13,800
Transformer losses...do....	10,500	10,500	10,500
Synchronous-condenser losses...do....	7,200	5,600	6,400
Total losses...do....	46,200	28,600	30,700
Efficiency of transmission...per cent..	86.7	91.3	90.7

COMMUNICATION LINES.

The superpower system can be operated successfully only through absolute unity of operating control. Relations must be established between the different parts of the system to insure unquestioning and immediate response to the directions of some central authority. This requirement involves facilities for instant communication between all the generating and distributing stations. Most of the existing transmission systems provide lines of communication that parallel the lines of transmission and that are supported by the transmission-line towers or by poles erected on the right of way. These lines of communication, supplemented in reserve by the Bell telephone systems for use between important centers, furnish adequate service.

The maintenance of lines of communication on the right of way of a high-tension transmission line that parallels power circuits, where they are particularly exposed to electrostatic and electromagnetic induction, is considered very undesirable by the power company, but it is employed as the surest means of maintaining communication between power plants and distributing stations. The commercial telephone systems have been so greatly improved and augmented that the telephone companies in the superpower zone now have great resources in trunk lines and alternate routes and exceptional facilities for maintaining their plants.

The operation of transmission lines by means of radio telephones or telegraph is being rapidly developed and will probably increase in the near future, particularly as radio communication is free from the effect of interference by high tension circuits.

SUBSTATIONS.

Outdoor substations of standard design, except as the design may be affected by higher voltages, will be used. Synchronous condensers will be installed in the substations to reduce investment and operating cost.

UNIT INVESTMENT COSTS.

TRANSMISSION LINES.

In the following table, showing the unit investment cost per mile for the different types of transmission lines used in existing systems, the cost includes rights of way and is based on prices in midyear of 1919.

TABLE 95.—*Unit investment cost for transmission lines.*

Line voltage.	Conductors.		Number of tower lines.	Total number of circuits.	Cost per mile.
	Material.	Area (circular mils).			
220,000	Aluminum Steel	605,000 78,000	1	2	$27,328
220,000	Aluminum Steel	605,000 78,000	2	4	54,056
220,000	Aluminum Steel	605,000 78,000	1	1	18,760
220,000	Aluminum Steel	605,000 78,000	2	2	36,920
220,000	Aluminum Steel	920,000 212,000	1	1	22,330
220,000	Aluminum Steel	920,000 212,000	2	2	44,060
110,000	Copper	No. 000	1	2	19,160
110,000	do	No. 000	2	4	37,070
110,000	do	350,000	1	1	16,780
110,000	do	350,000	2	2	32,310
110,000	Aluminum Steel	450,000 58,500	1	2	20,945
110,000	Aluminum Steel	450,000 58,500	2	4	40,640
110,000	Aluminum Steel	920,000 212,000	1	2	33,440
110,000	Aluminum Steel	920,000 212,000	2	4	65,630

SUBSTATIONS.

Figure 56 shows the unit cost of 110,000-volt substations with low-tension secondaries in midyear of 1919. This cost includes transformers, structures, and switch gear to accommodate two, four, six, or eight incoming 110,000-volt lines.

Figure 57 shows the unit cost of 220,000-volt substations with low-tension secondaries in midyear of 1919. This cost includes transformers, structures, and switch gear to accommodate two or four incoming 220,000-volt lines.

Figure 58 shows the unit cost of 220,000-volt substations with 110,000-volt secondaries in midyear of 1919. This cost includes transformers, structures, and switch gear to accommodate two, four, or six incoming 220,000-volt circuits and six outgoing 110,000-volt circuits.

SYNCHRONOUS-CONDENSER STATIONS.

Figure 59 shows the unit cost of synchronous-condenser stations at midyear of 1919. This cost includes buildings, synchronous condensers, transformers, and switching and regulating equipment. For the operation of synchronous condensers on 110,000-volt circuits independent transformers are provided; for 220,000-volt circuits a tertiary winding is added to the main transformers.

FREQUENCY-CHANGER STATIONS.

Figure 60 shows the unit cost of frequency-changer stations at midyear of 1919. This cost includes building, frequency changers, transformers, and switching and regulating equipment.

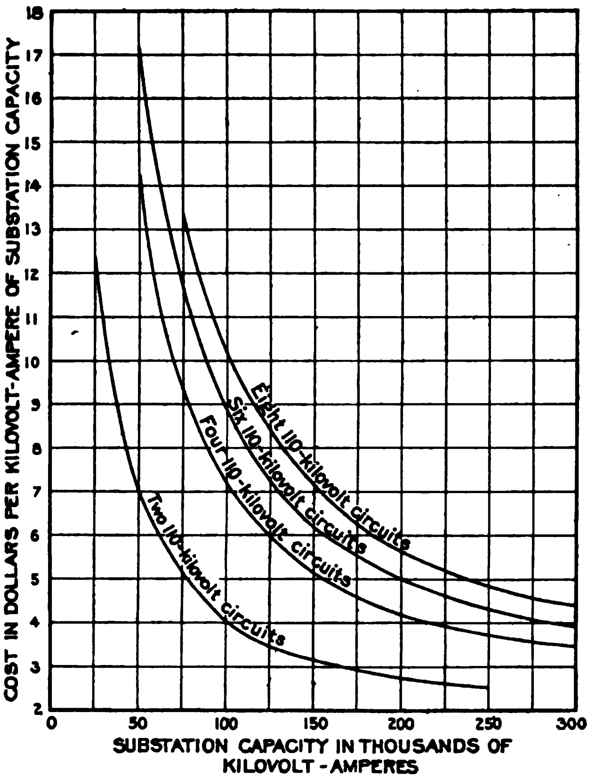


FIGURE 56.—Unit cost of 110,000-volt 60-cycle substations with low-tension secondaries in midyear of 1919.

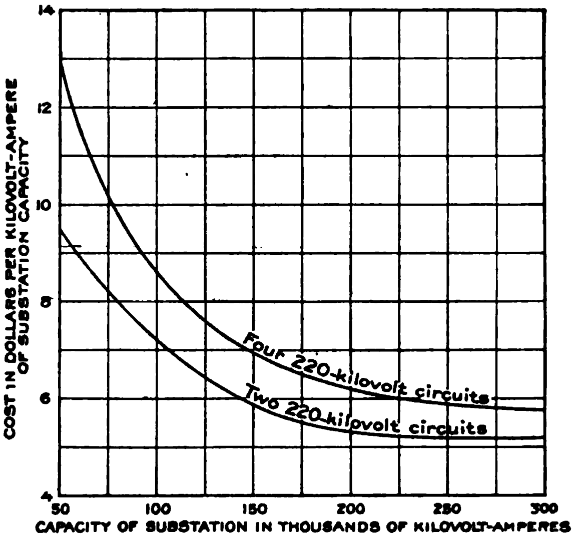


FIGURE 57.—Unit cost of 220,000-volt 60-cycle substations with low-tension secondaries in midyear of 1919.

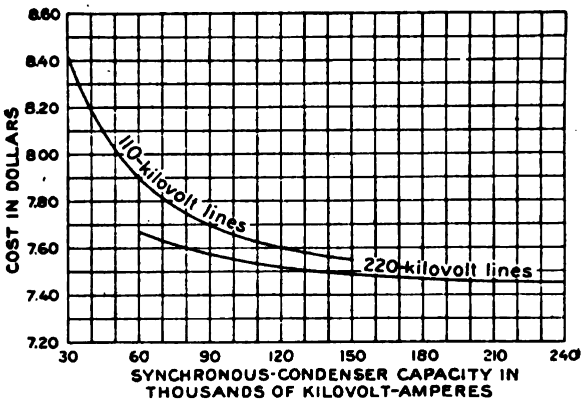


FIGURE 59.—Estimated cost per kilovolt-ampere of capacity of 60-cycle synchronous condensers in midyear of 1919.

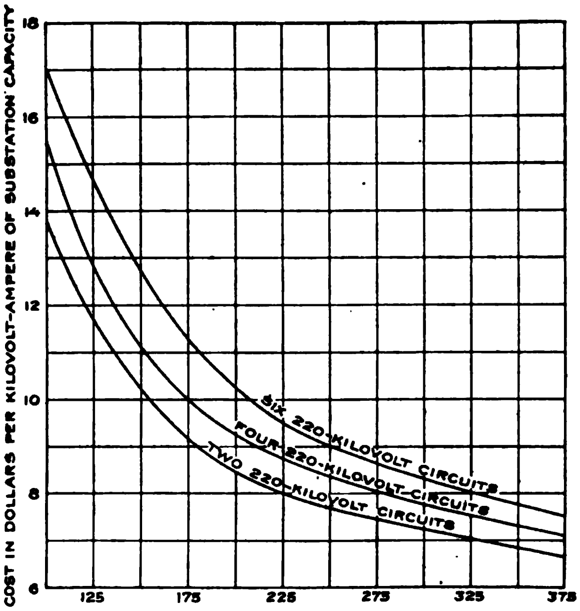


FIGURE 58.—Unit cost of 220,000-volt 60-cycle substations with 110,000-volt secondaries in midyear of 1919.

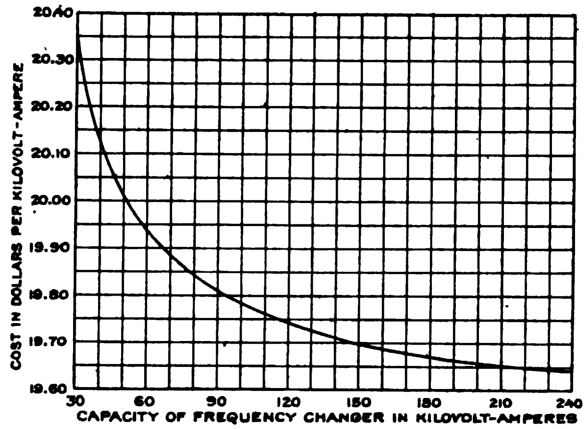


FIGURE 60.—Unit cost of frequency-changer stations in midyear of 1919. Applies to installations of 110,000 or 220,000 volts, 25 or 60 cycles.

OPERATING COST OF TRANSMISSION SYSTEM.

TRANSMISSION LINES.

The following estimated operating cost for transmission lines includes maintenance, labor, and supplies and is based on the actual cost of operating long-distance lines:

TABLE 96.—*Operating cost for transmission lines.*

Line voltage.	Number of tower lines.	Total number of circuits.	Operating cost per mile per year.
220,000	1	1	$175
	1	2	200
	2	2	225
	2	4	250
110,000	1	1	125
	1	2	150
	2	2	200
	2	4	250

SUBSTATIONS.

The annual cost of maintenance and supplies has been fixed at 2 per cent of the total first cost of the substation. For the annual cost of labor $12,000 is used for substations having a capacity of 150,000 kilovolt-amperes or less, $18,000 for those having capacities between 150,000 and 300,000 kilovolt-amperes, and $24,000 for those having capacities of more than 300,000 kilovolt-amperes.

APPENDIX I.

RELIABILITY OF SERVICE.

By L. E. Imlay and others of the engineering staff.

Reliability of service is of first importance. A superpower system with interconnection through many load centers and with provision for obtaining power from several sources can insure continuous service.

Modern power plants, which use large units, are simple compared to power plants built a decade ago. The tendency to locate the plants outside of centers of population has done much to simplify former complicated switching and feeder arrangements.

The principal causes of power-plant interruption, outside of fluctuations in coal supply, are in the coal-handling, boiler, turbine, condenser, and electrical apparatus. Provision is made against such interruptions in the superpower system.

Coal-handling equipment is now provided either in duplicate or of sufficient capacity so that the coal supply will not be in danger of exhaustion. To the popular mind boiler explosions are regarded as one of the greatest dangers to be apprehended in steam plants, but since the advent of the water-tube boiler there is, so far as explosions are concerned, no limitation to the number and capacity of boilers that may be placed in one plant.

Large steam turbines of recent development have excellent records for continuous operation over long periods. It is true that during the World War considerable trouble was experienced with a number of large turbines, but the cause of this particular trouble has been accurately ascertained and eliminated.

The operating records of turbine units in a number of large plants show that these units are available for service more than 90 per cent of the time, and the margin is within the reserve capacity of the plant.

It is difficult in a well-operated plant to justify interruptions from condenser troubles.

Failures in modern electric generators are no longer frequent. The perfection of oil switches and the complete isolation of the phases and reactance applications have resulted in the elimination of the disastrous effects of short circuits.

Superpower transmission will involve capacities of 300,000 kilowatts and maximum distances of 350 miles. Consultation and exhaustive discussion with the principal transmission authorities of this country regarding a proper support and circuit arrangement led to the conclusion that these transmission systems should consist of two tower lines, each supporting two circuits and each tower line being capable of transmitting the entire load.

Load centers in the past have usually been dependent upon a single transmission line. By virtue of its interconnecting network the superpower system will eliminate the hazard of interruption or disaster from the use of a single line.

The transmission systems for the superpower system will be of entirely different dimensions from those to which we have become accustomed. Appendix H–2 brings out the features of their construction. Their reliability will be of the same order as that prevailing within the best modern power plants. They can thus be considered as merely high-tension extensions of the power-plant busses.

The inherent characteristic of the superpower system, therefore, is adequate provision for reserves through its entire structure.

APPENDIX J.

THE RELATION OF COAL AND COAL-DELIVERY ROUTES TO THE SUPERPOWER SYSTEM.

By C. E. Lesher, F. G. Tryon, and others.

DISTRIBUTION AND USE OF COAL IN THE SUPERPOWER ZONE IN 1919.

Table 97 shows that the coal used by central stations is only about 9 per cent of the total used in the superpower zone; that used for locomotive fuel and other railroad purposes and by industries, mines, Government institutions, waterworks, and the central stations amounts to nearly 71 per cent of the total.

Table 97.—*Distribution and use of coal in superpower zone for 1919, in short tons.*

	Bituminous.	Anthracite.	Total.
Sources:			
Mined in zone	None.	87,607,000	87,607,000
Shipped into zone for consumption therein or for bunker and sea-borne export:			
Imports by water from Canada	3,000	None.	3,000
By rail from United States	70,706,600	143,000	70,849,000
Coastwise from Hampton Roads	7,000,000	None.	7,000,000
Total coal available	77,709,000	87,750,000	165,459,000
Used in zone:			
Railroads:			
Locomotive fuel, class 1 roads	15,640,000	2,765,000	18,405,000
All other railroad supply coal except coal for repair shops, including coal for heating stations and all coal for roads other than class 1	1,830,000	1,880,000	3,710,000
Central electric stations	9,976,000	1,830,000	11,806,000
Industries, mines, and Government institutions	34,669,000	23,419,000	58,088,000
Waterworks	260,000	291,000	551,000
Heating residences and all other buildings not elsewhere specified. Includes coal burned in dwellings, apartment houses, hotels, restaurants, theaters, office buildings, schools, hospitals, churches, public buildings, and State, county, and municipal institutions	4,600,000	34,459,000	39,059,000
Total used in zone	66,975,000	64,644,000	131,619,000
Shipped out of zone:			
Foreign bunker	4,669,000	None.	4,669,000
Domestic bunker, including bunker for Army transports and Navy	2,970,000	None.	2,970,000
Sea-borne exports	3,095,000	152,000	3,247,000
Coal mined in zone but shipped by rail out of zone	None.	22,954,000	22,954,000
Total coal leaving zone	10,734,000	23,106,000	33,840,000

COAL DISTRICTS AND COAL DELIVERY ROUTES.

The bituminous-coal districts tributary to the superpower zone are the Clearfield, Somerset, Windber, Greensburg, Westmoreland, Pittsburgh, Fairmont, Georges Creek, Pocahontas, New River, and Kanawha.

The Clearfield, Somerset, and Windber districts lie nearest, and the freight rate from them is the lowest, but they are within the thin-seam regions, where the production cost is high.

The Westmoreland, Greensburg, Pittsburgh, and Fairmont districts are in the thicker-seam region, where production costs are lower, but the freight rates from them are higher.

About half of New England's coal has heretofore been supplied from the Pocahontas, New River, and Kanawha districts. These districts are the chief sources of coal for export, and when the export demand is large the demand in New England must compete with it.

The selection of sites for base-load steam-electric plants is dependent upon the availability of sufficient condensing water, the cost of coal delivered, and the relation of the plant site to the coal-delivery routes from the mines.

Power plants at tidewater in New England east of New London have a reliable coal supply, as they can obtain fuel from the greatest number of sources, having the option of either all-rail or rail and water delivery. The two particular difficulties in the free movement of coal to New England are congestion at times at the Hudson River gateways, due to weather and traffic conditions, and the shortage of bottoms at certain periods for the movement of coal from Baltimore, Philadelphia, and Hampton Roads to eastern New England ports.

The principal bituminous-coal carriers to the superpower zone are the Pennsylvania, the Baltimore & Ohio, the New York Central, and the Western Maryland. These railroads are also the principal carriers of all other traffic to that zone, and at times the traffic demand exceeds their capacity. At certain points on these lines, such as the classification yards at Cumberland, Altoona, Williamsport, and Harrisburg, congestion has occurred through either the traffic conditions or the topographic conditions; at others congestion is due primarily to the necessity of transfer between the railroads, as at Troy, Albany, Maybrook, and Harlem River.

Plants on Hudson River as far north as Troy can readily receive coal, either through Albany or by river barges from New York Harbor. Between New York and Washington there are a number of good locations for steam-electric power plants. Sites are available along New York Bay, Hackensack River, Passaic River, Raritan Bay, Raritan River, Delaware River as far north as Trenton, Delaware Bay, Chesapeake Bay, and Potomac River as far west as Cumberland. In the inland region Susquehanna River and its branches offer excellent sites for the location of base-load steam-electric plants.

The principal difficulty in the location of steam-electric plants in the bituminous mining districts comes from lack of condensing water. (See Appendix F.)

Plate X shows the location of available coal-mining districts, principal rail routes, and location of base-load steam-electric plants for 1930. Anthracite is not discussed at this time, for plants constructed to burn anthracite will be located in the mining region, and rail delivery will consist only in gathering the coal for them. Power can be delivered to the Newark and Philadelphia load centers from plants to be constructed in the anthracite region more cheaply than power can be generated at these centers. (See Appendix F.)

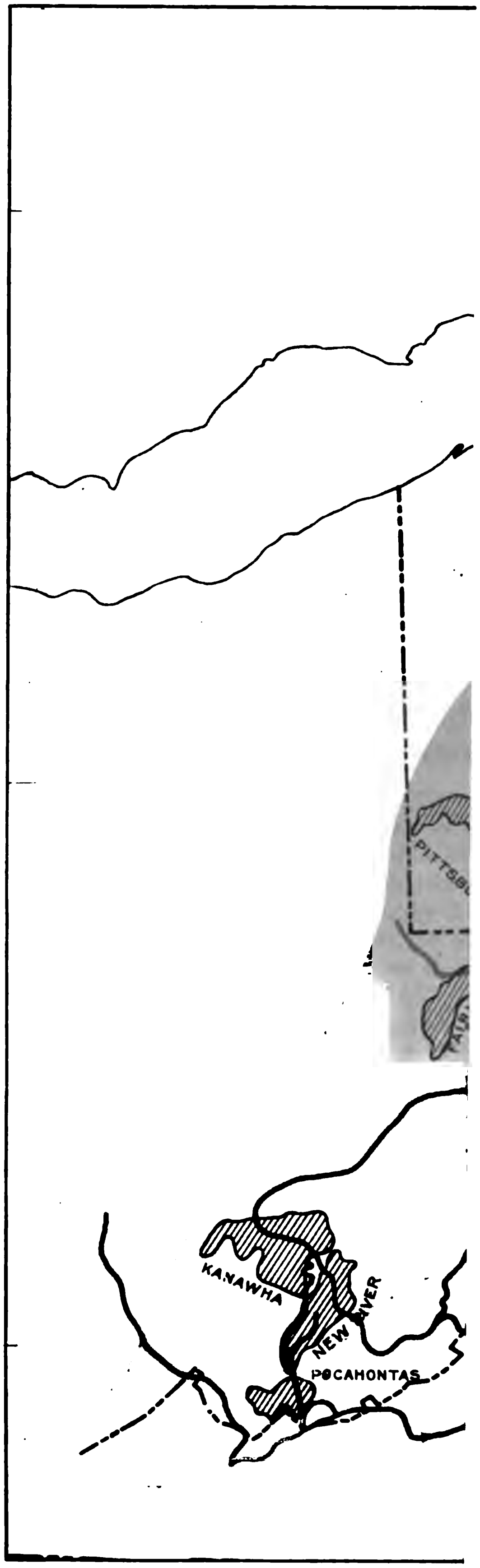
COST OF COAL.

COST OF COAL AT THE MINES.

Bituminous coal.—The average price for bituminous coal at the mine has been taken at $2.90 per short ton for the three years considered (1919, 1925, and 1930) and was determined by the weighted average cost of bituminous coal for 1919 to the fuel-using industries in the superpower zone. This price applies to fuels that take the Clearfield freight rate. The Greensburg, Westmoreland, Pittsburgh, and Fairmont districts, which ship coal to the superpower zone by rail and water, as well as by all-rail routes, sell at a price about 50 cents a short ton lower than the Clearfield district. The Pocahontas, New River, and Kanawha fields supply large amounts of coal to eastern New England by boat, delivered from Hampton Roads. This coal commands a premium of about 50 cents a short ton at the mine over that of the Clearfield district.

Although the cost of labor may be reduced by modification of the present wage scale, which terminates in 1922, the cost of coal tends to increase gradually from the necessity of developing mines in thinner seams and deeper veins and of extending underground haulage in existing mines.

Anthracite.—The price for buckwheat No. 3 coal at the mines has been taken at $1.75 per long ton for the three years considered (1919, 1925 and 1930). This price is based on records of sales made in 1919 and on the competitive relation between anthracite and bituminous coal at tidewater delivery points.



LOCATION OF PRI

Between 1911 and 1917 the ratio of the cost of buckwheat No. 3 coal at New York Harbor to the cost of low-volatile bituminous coal increased from 53 to 56 per cent. In 1918 it jumped to about 67 per cent, but in 1919 it fell to 66 per cent. The large increase in 1918 and 1919 was due to the fact that bituminous coal was then under governmental regulation, while buckwheat No. 3 coal was not, and it was further due to the difficulty of obtaining deliveries of bituminous coal. The New York Harbor price of buckwheat No. 3 coal has been taken at approximately 63 per cent of the price of low-volatile bituminous. Although this ratio is somewhat higher than that in existence before the war, it is considered reasonable, as the demand for buckwheat No. 3 coal has increased through the development of anthracite stokers and better knowledge of the use of this coal gained during the war.

United States Geological Survey records show that 78,501,931 long tons of anthracite was mined in 1919. Of this total 67,817,284 tons was shipped out of the anthracite district and 8,576,850 tons was used for fuel by the mines themselves. Local sales account for the remainder. The total quantity of buckwheat No. 3 and smaller sizes of anthracite shipped in 1919 was 3,759,000 tons.

Large base-load steam-electric plants located in the anthracite region will require approximately 1,600,000 long tons of buckwheat No. 3 and smaller sizes of anthracite for each 300,000-kilowatt plant, which is nearly one-half of the total of those sizes shipped in 1919. However, a large proportion of the mines that now have their own steam plants would be electrified when such power plants were constructed, thus releasing, owing to the higher efficiency of the power plants, a larger amount of the small steam sizes than would be required for the operation of these base-load plants. Under such conditions the demand will not be in excess of the supply. (See Appendix F.)

COST OF COAL DELIVERED TO THE STEAM-ELECTRIC PLANTS.

The cost of fuel at the power plants has been determined by the cost of coal from the Clearfield district.

Coal from the Westmoreland, Greensburg, Pittsburgh, and Fairmont districts costs 50 cents a short ton less than Clearfield coal but is lower in calorific value. Coal from the Pocahontas, New River, and Kanawha fields has a higher calorific value than that of Clearfield, but its mine price is 50 cents a short ton higher. When all charges to the destination point are considered, the number of British thermal units obtained for each dollar expended is nearly the same for coal from all the fields, and the use of the Clearfield prices and freight rates as a basis both for fuel cost and plant performance gives a representative average.

The current freight rates of 1919 are used in the calculations for that year and those existing on January 1, 1921, for the 1925–1930 period.

Table 98 gives the cost of bituminous coal at specified destination points from those fields that are tributary to them.

TABLE 98.—*Cost of bituminous coal per short ton at destination points in the superpower zone.*

Load center.	Mining district.	Period.	Price at mines.	Freight, taxes, insurance, and seasonal coal storage.	Total cost in plant bunkers.
Boston	Clearfield	1919	$2.90	$3.16	$6.06
	.....do	1925–1930	2.90	4.45	7.35
	Fairmont	1925–1930	2.45	4.68	7.13
	Pocahontas	1925–1930	3.35	5.40	8.75
Providence	Clearfield	1919	2.90	3.24	6.14
	.....do	1925–1930	2.90	4.59	7.49
	Fairmont	1925–1930	2.45	4.81	7.26
	Pocahontas	1925–1930	3.35	5.15	8.50
New London	Clearfield	1919	2.90	2.79	5.69
	.....do	1925–1930	2.90	3.93	6.83
	Fairmont	1925–1930	2.45	4.16	6.61
	Pocahontas	1925–1930	3.35	5.40	8.75

TABLE 98.—*Cost of bituminous coal per short ton at destination points in the superpower zone*—Continued.

Load center.	Mining district.	Period.	Price at mines.	Freight, taxes, insurance, and seasonal coal storage.	Total cost in plant bunkers.
New Haven	Clearfield	1919	$2.90	$2.68	$5.58
	.....do	1925–1930	2.90	3.81	6.71
	Fairmont	1925–1930	2.45	4.18	6.63
Hartford	Clearfield	1919	2.90	3.06	5.96
	.....do	1925–1930	2.90	4.33	7.23
	Fairmont	1925–1930	2.45	4.55	7.00
Northampton	Clearfield	1919	2.90	3.42	6.32
	.....do	1925–1930	2.90	4.83	7.73
	Fairmont	1925–1930	2.45	5.07	7.52
Albany and Poughkeepsie	Clearfield	1919	2.90	2.42	5.32
	.....do	1925–1930	2.90	3.43	6.33
	Fairmont	1925–1930	2.45	3.80	6.25
New York, Newark, and New Brunswick.	Clearfield	1919	2.90	2.32	5.22
	.....do	1925–1930	2.90	3.35	6.25
	Fairmont	1925–1930	2.45	3.66	6.11
Trenton	Clearfield	1919	2.90	2.23	5.13
	.....do	1925–1930	2.90	3.17	6.07
	Fairmont	1925–1930	2.45	3.40	5.85
Harrisburg	Clearfield	1919	2.90	1.77	4.67
	.....do	1925–1930	2.90	2.53	5.43
	Fairmont	1925–1930	2.45	2.77	5.22
Philadelphia, Wilmington, Baltimore, and Washington.	Clearfield	1919	2.90	2.15	5.05
	.....do	1925–1930	2.90	3.05	5.95
	Fairmont	1925–1930	2.45	3.27	4.72

OWNERSHIP OF COAL MINES.

No advantage has been found in the ownership of coal mines by the power company to offset the elimination of the flexibility of supply, the increase in initial investment, the additional administrative cost, and the hazard common to mining enterprises.

COAL STORAGE.

A 360,000-kilowatt plant at an annual capacity factor of 60 per cent will use 1,260,000 short tons of bituminous coal a year. Storage of six months' coal supply for such a plant will therefore require 630,000 tons. Coal storage in this amount might appear excessive, but the following advantages are evident: (1) It would absolutely prevent interruption of service due to lack of fuel. (2) It would permit the purchase of coal at the lowest market price. Where facilities for coal storage are scanty, the purchase of coal in the spot market at times of shortage and without regard to quality results in an excessive expense, which would more than offset the cost of adequate storage facilities. (3) It would effect partial stabilization of the mining and the transportation industries through bringing about a more uniform demand for fuel and thus tending to increase the operating load factor of these two industries. It is equally obvious that this would be a step toward reducing the price of fuel to the consumer because it would be a step in the reduction of cost of mining and transportation.

There has been some discussion with regard to the ownership by the superpower system of either coal cars or railroad routes or both, but it has been concluded that the superpower system should confine its activities to the production of power and the storage of coal.

The cost of coal storage is included in the production cost of the superpower system.

APPENDIX K.

USE OF PROCESS FUELS AND PULVERIZED COAL FOR BASE-LOAD STEAM-ELECTRIC PLANTS.

By O. P. Hood and others of the engineering staff.

CONCLUSIONS RELATIVE TO THE USE OF PROCESS FUELS.

In considering the use of process fuels by base-load steam-electric stations it has been necessary to fix certain limitations to the study, which must necessarily be a general one covering the entire superpower zone. The study was therefore confined to processes that had reached the stage of commercial development. The fixed charges against the investment cost in the by-product plants have invariably been taken at 20 per cent—10 per cent for the cost of money, 8 per cent for depreciation and obsolescence, and 2 per cent for taxes and insurance. At the same time the operating costs have been taken at $1.35 per ton of coal carbonized, and the prices credited for by-products are those given below.

In a base-load steam-electric plant under present conditions coal must generally be used in the raw form in order to produce cheap power. Local conditions will justify certain exceptions to this practice. At large centers of population it may be found profitable to install process-fuel plants in conjunction with base-load steam-electric stations if the gas produced by the plants can be sold at a profit, particularly where a process is used that will yield gas which has a very high heating value and which can be used to enrich water gas made by the gas companies.

Coal is subjected to a preliminary process for two purposes—to place its energy in a more desirable form and to recover valuable products. If power is produced by the use of either coke or gas from process-fuel plants the value of the remaining products, when credited to the cost of such fuels, is not sufficient to reduce the cost below that of raw coal. As certain by-products are essential in time of war regardless of cost, however, it is desirable in selecting a site for a superpower plant to provide space for a processing plant.

Accordingly, provision is made in the estimated costs for base-load steam-electric plants both for the location of process-fuel plants and for boiler-room construction that will permit the use of process fuel at a later date if it is found advisable.

SOURCES OF PROCESS FUELS.

Four sources of process fuels for base-load steam-electric plants have been considered—by-product coke-oven plants furnishing coke, by-product coke-oven plants furnishing gas, low-temperature distillation plants furnishing semicarbocoal, and bituminous gas producers furnishing gas.

The credits used for by-products are as follows:

Gas, 30 cents per thousand cubic feet.
Tar, 4 cents per gallon.
Light oils, 15 cents per gallon.
Ammonium sulphate, 2½ cents per pound.
Coke, including breeze, $10 per short ton.

The base-load steam-electric plants for which process fuel will be furnished are assumed to be 300,000-kilowatt plants having an annual capacity factor of 70 per cent. Sufficient process-fuel plant capacity must be provided to meet variations in the load of the steam-electric plants.

The average cost of gas coal for carbonization is taken at $6.11 per short ton; the cost of Clearfield coal used directly in the power plant is taken at $6.25 per short ton.

For process-fuel plants the unit operating cost exclusive of fuel has been placed at $1.35 per short ton of coal carbonized, and the fixed charges have been taken at 20 per cent.

Table 99 gives the result of this study. With the exception of gas from by-product coke-oven plants, process fuel is shown to cost more than coal. Moreover, the heavy investment required for a coke-oven plant producing gas as the process fuel, combined with the transportation difficulties in distributing the by-products, makes its use as a source of process fuel impracticable. The coke produced by one such plant would amount to 26 per cent of the total present coke requirement of the superpower zone, and even if the existing coke-producing facilities in the zone are ignored, it would require only four plants of this size to satisfy the entire coke demand of the zone. Furthermore, over 760 special railroad cars daily would be required to distribute the coke output of one such plant to its market and at the same time about 590 cars additional to bring the coal to the plant. Compared to this, only about 70 cars a day would be needed to convey coal to the 300,000-kilowatt steam-electric plant burning raw coal.

For low-temperature distillation plants the by-products have been credited at $4.22 per short ton of coal carbonized, which is 28 cents less than the credits claimed by the Carbo Coal Co., but this difference is immaterial, because to make this process profitable under present conditions more than $5.15 per short ton of coal carbonized must be realized from the by-products. Although the carbocoal process has been selected for analysis, as it is further advanced technically than any of the other low-temperature distillation processes, semicarbocoal has not yet been used extensively in large power plants.

It is fundamentally necessary, where the processing of fuel is combined with the production of power, that a minimum number of heat units be lost to the steam-electric plant. Tar, oils, and ammonium sulphate contain relatively few heat units, and therefore in the recovery of these by-products a large portion of the original heat units remain available for making steam.

The results set forth above justify the conclusions given in the preceding section.

USE OF GAS FROM PROCESS-FUEL PLANTS IN INTERNAL-COMBUSTION ENGINES.

Gas engines have a higher thermal efficiency than prime movers that use steam, but they are so deficient in other characteristics that they can not at present be considered for superpower plants. The gas engine has not been developed in units of a size comparable with steam turbines, and investment and production costs for gas engines are much higher. These disadvantages outweigh the advantage gained by their higher thermal efficiency.

PULVERIZED COAL.

Pulverized coal has been successfully used in cement kilns and metallurgic furnaces for some time, but it is only in recent years that sufficient progress has been made in its adaptation to boiler furnaces to warrant its consideration. However, no large power plants have used this form of fuel long enough to give a reliable indication of the results.

As the future development of firing pulverized fuel may warrant its substitution for stokers, provision is made in the power station for sufficient combustion-chamber volume to allow the installation to be quickly and cheaply changed.

COST.

Table 99.—*Relative cost of process fuel and of coal for 300,000-kilowatt base-load steam-electric plants for the superpower system.*

	Coke from by-product coke ovens.	Gas from by-product coke ovens.	Semicarbocoal from low-temperature distillation plants.	Gas from bituminous gas producers.
Raw-fuel plant:				
Annual capacity factor..........................per cent..	70	70	70	70
Clearfield coal required per year for stoker operation, short tons..	1,200,000	1,200,000	1,200,000	1,200,000
Process-fuel plant:				
Annual capacity factor..........................per cent..	80	70	80	70
Carbonization capacity:				
Daily......................................short tons..	6,850	42,000	6,850	7,570
Per year.......................................do....	2,000,000	10,800,000	2,000,000	1,930,000
Resulting coke or semicarbocoal.....................do....	1,410,000	7,550,000	1,410,000	....
Investment required:				
Total..	$14,400,000	$88,000,000	$14,400,000	$22,710,000
Per cent of investment in power plant................	45	280	45	71
Annual operating expense...............................	$14,920,000	$80,600,000	$14,920,000	$14,400,000
Annual fixed charges...................................	2,880,000	17,600,000	2,880,000	4,542,000
Total annual production expense....................	17,800,000	98,200,000	17,800,000	18,942,000
Credit from by-products except coke....................	6,240,000	16,600,000	8,440,000	6,180,000
	11,560,000	81,600,000	9,360,000	12,762,000
Return from coke sold..................................	....	75,550,000	....	....
Net annual cost of fuel..........................	11,560,000	6,050,000	9,360,000	12,762,000
Cost of 1,200,000 tons of Clearfield coal for use raw............	7,500,000	7,500,000	7,500,000	7,500,000
Difference:				
Total...	4,060,000	−1,450,000	1,860,000	5,262,000
Per short ton of Clearfield coal.....................	$3.38	−$1.21	$1.55	$4.38

APPENDIX L.

BASIC COSTS.

By the engineering staff.

CONSTRUCTION COSTS.

The costs for labor and materials in construction prevailing at midyear of 1919 are used unless otherwise specified.

FIXED CHARGES AGAINST INVESTMENT.

Fixed charges against investment have been subdivided into cost of money, depreciation and obsolescence, and taxes and insurance.

Cost of money.—Ten per cent has been taken as the cost of money for investments of all classes. The term "cost of money" is used to express the allowable return upon investment; it includes the rate of interest, discounts, and profit. The resulting final costs are the price at which energy can be sold by the superpower system with proper return upon its investment.

Depreciation and obsolescence.—The charge for depreciation and obsolescence is varied to provide reserves on an annuity basis for the several classes of investment against which it is figured. The percentages used are as follows:

	Per cent.
Steam-electric power plants	4
Hydroelectric power plants	3
Hydraulic works	1
Transmission lines	2
Substations	4

Taxes and insurance.—The following percentages have been used for taxes and insurance:

	Per cent.
Steam-electric power plants	2
Complete hydroelectric developments	1.5
Transmission lines	1.5
Substations	2

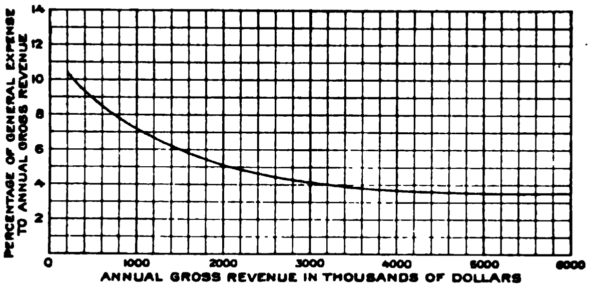


FIGURE 61.—Relation of general expense to annual gross revenue for 60 electric-utility companies in the superpower zone. Amortization fund, interest, taxes, and miscellaneous adjustments have been deducted.

GENERAL EXPENSE.

General expense includes provision for salaries and expenses of administrative officers, engineers, and legal counsel, salaries of clerks, claims, general stationery, printing, and store and stable expenses. Amortization, taxes, and insurance have been included under fixed charges rather than under general expense.

An examination of public-service commission records for 60 electric-utility companies in the superpower zone showed that general expense ranges from about 10.5 per cent for a gross annual revenue of $200,000 to about 3.5 per cent for a gross annual revenue of $5,000,000 or more, as is shown by figure 61.

OVERHEAD CHARGES AGAINST CONSTRUCTION.

The rate used for interest during construction is 7½ per cent, and this rate applied to the construction period for different classes of work results in the following charges: Steam-electric plants, 4½ per cent; hydroelectric plants, 6 per cent; transmission lines and substations, 3 per cent. Taxes during construction are figured at 1 per cent. Superintendence, engineering, and contingencies are figured at 15 per cent.

APPENDIX M.

STATIONS AND TRANSMISSION LINES OF ELECTRIC-POWER COMPANIES ENGAGED IN PUBLIC SERVICE.

By A. H. HORTON.

The information given on Plate XI (in pocket) has been obtained from the power companies in the following manner: A proof map showing the stations and transmission lines of the public-utility companies in each State included in the superpower zone was prepared from the best information that could be obtained. A section of this map showing the stations and transmission lines operated by each company was sent to that company, which was requested to examine the map and report to the Geological Survey any errors detected or any changes that should be made. From the corrections and additions thus received a revised map of each State was prepared. The location of the power stations and transmission lines of those companies which did not reply to requests for information was determined from available published sources.

The maps were prepared to be published as separate State maps, and the accompanying map of the northeastern United States has been produced from these State maps by photolithography. The general outline of the superpower zone is shown on the map. In some of the congested areas in and around the large cities it was not possible to show all the power stations and transmission lines. However, the names and addresses of the companies that produce electricity for public use are shown in the following list, which includes the names of all companies in each State, even though only a portion of the State is shown on the map. The information on the map for New England and New York represents conditions in 1919; for Pennsylvania, New Jersey, Maryland, the District of Columbia, and Delaware, 1920; and for Virginia, 1921.

In this list the names of the operating companies are arranged in alphabetic order, and the corresponding file numbers assigned to them are in general arranged in numerical order. These file numbers are those used by the Geological Survey in its list of public utilities engaged in the production or distribution of electric energy. Where the numerical order conflicts with the alphabetic order the latter is followed, but the file number is repeated in the proper place, with the name of the operating company. Disarrangement of the numerical order is due to changes in the ownership of companies and to the inclusion in the list of certain manufacturing companies which sell for public use a part of the current they generate for manufacturing and which are distinguished by a different system of file numbers. The generating stations of a company that operates more than one station are indicated by letters (A, B, C, etc.) placed after the file numbers, as 5905–A; the substations of a company that operates more than one substation are indicated by prefixing figures (1, 2, 3, etc.) to the file numbers, as 1–5985. The file number assigned to a company added to the list after consecutive numbers had been assigned to companies preceding and following it consists of the preceding number with a figure added, as 5985–1. A file number that contains more than four digits indicates a company that is not engaged primarily in producing electric power or not operated as a public utility.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated.*

Connecticut.

No.	Operating company.	Station.
900	Baltic Mills Co	Baltic.
901	Beacon Falls Electric Co	Beacon Falls.
902	Bristol & Plainville Tramway Co	Bristol.
903	Clinton Electric Light & Power Co	Clinton.
904	Central Connecticut Power & Light Co	Leesville.
24095	Cheney Bros	Manchester.
903	Clinton Electric Light & Power Co	Clinton.
906	Connecticut Co.:	
	A	Berlin.
	B	Bridgeport.
	C	Burrville.
	D	New Haven.
	F	West Haven.
	G	Hartford.
	H	Shelton.
	J	Danielson.
907	See Connecticut Power Co	Canaan, etc.
920	Connecticut Light & Power Co.:	
	A	Branford.
	B	Waterbury.
	C	Bulls Bridge.
	D	Stevenson.
907	Connecticut Power Co.:	
	A	Canaan.
	B	Falls Village.
	C	Middletown.
	D	New London.
909	Danbury & Bethel Gas & Electric Light Co	Danbury.
910	Danbury & Bethel Street Railway Co	Do.
911	Danielson & Plainfield Gas & Electric Co	Plainfield.
912	Derby Gas Co	Derby.
24136	Dunham Mills (Inc.)	Poquonock.
913	Eastern Connecticut Power Co.:	
	A	Montville.
	B	Tunnel.
	C	Hallville.
915	Essex Light & Power Co	Essex.
24150	Farmington River Power Co	Windsor.
917	Hartford Electric Light Co.:	
	A	Tariffville.
	B	Dutch Point.
918	Hartford & Springfield Street Railway Co	Warehouse Point.
24211	International Cotton Co	New Hartford.
920	*See* Connecticut Light & Power Co	Branford, etc.
921	Kent Electric Light & Gas Co	Kent.
922	Litchfield Electric Light & Power Co	Bantam.
924	Lyme Electric Power Co	Lyme.
951	Manchester Electric Co	South Manchester.
925	Meriden Electric Light Co	Meriden.
927	Municipal electric plant	Jewett City.
928	do	East Norwalk.
929	do	Norwich.
930	South Norwalk Electric Works	South Norwalk.
931	Municipal electric plant:	
	A	Wallingford.
	B	North Haven.
932	Mystic Power Co	Westerly.
934	New Hartford Electric Co	New Hartford.
936	New Milford Electric Light Co	New Milford.
938	New York, New Haven & Hartford Railroad Co	Coscob.
939	Northern Connecticut Light & Power Co	Windsor Locks.
942	Peoples Light & Power Co	Danielson.
945	Putnam Light & Power Co	Mechanicsville.
946	Ridgefield Electric Co	Ridgefield.
947	Rockville-Willimantic Lighting Co.:	
	A	Rockville.
	B	Stafford.
	C	Willimantic.
24376	Scovill Manufacturing Co	Waterbury.
949	Shore Line Electric Railway Co.:	
	A	Saybrook.
	B	Thamesville.
	D	Mystic.
	F	New London.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

No.	Operating company.	Station.
	Connecticut—Continued.	
950	Simsbury Electric Co.	Simsbury.
930	South Norwalk Electric Works	South Norwalk.
951	Manchester Electric Co.	South Manchester.
952	Stamford Gas & Electric Co.	Stamford.
953	Talcott Bros.	Talcottville.
955	Torrington Electric Light Co.	Torrington.
957	Uncas Power Co.	Windham.
958	Union Electric Light & Power Co.	Unionville.
960	United Illuminating Co.:	
	A	Bridgeport.
	B	New Haven.
963	Westport Water Co.	Westport.
24773	Winchester Repeating Arms Co.	New Haven.
965	Winsted Gas Co.	Winsted.
966	Woodbury Electric Co.	Woodbury.
24095	Cheney Bros.	Manchester.
24136	Dunham Mills (Inc.)	Poquonock.
24150	Farmington River Power Co.	Windsor.
24211	International Cotton Co.	New Hartford.
24376	Scovill Manufacturing Co.	Waterbury.
24473	Winchester Repeating Arms Co.	New Haven.
	District of Columbia.	
1051	Capital Traction Co.	Georgetown.
1051-1	East Washington Heights Traction Railroad Co.	Washington.
1052	Potomac Electric Power Co.:	
	A	Bennings.
	B	Fourteenth Street.
1053	Washington Railway & Electric Co.	Washington.
1054	Washington-Virginia Railway Co.	Do.
	Maine.	
3300	Androscoggin Electric Co.:	
	A	Barkers Mills.
	B	Deer Rip No. 1.
	C	Lewiston No. 4.
	D	Littlefield No. 2.
3347	Androscoggin & Kennebec Railway Co.	Hallowell.
3301	Aroostook Valley Railroad Co.	Presque Isle.
3302	Atlantic Shore Railway Co.:	
	A	Estes.
	B	Kennebunkport.
	D	Old Falls.
3303	Bangor Power Co.:	
	A	Milford.
	B	Veazie.
3304	Bangor Railway & Electric Co.	Bangor.
3305	Bar Harbor & Union River Power Co.	Ellsworth.
3306	C. H. Bartlett Manufacturing Co.	North New Portland.
3307	Belgrade Power Co.	Belgrade.
3309	Berwick & Salmon Falls Electric Co.	South Berwick.
3310	Bethel Light Co.	Bethel.
3313	Bridgewater Electric Co.	Bridgewater Center.
3314	Bridgton Water & Electric Co.	Bridgton.
3315	Brownville Electric Light & Power Co.	Brownville.
3318	Calais Street Railway Co.:	
	A	Calais.
	B	Do.
3319	Carrabassett Light & Power Co.	North Anson.
3320	Caribou Water, Light & Power Co.	Caribou.
3321	Central Maine Power Co.:	
	A	Augusta.
	B	Bath.
	C	Belfast.
	D	Brunswick.
	E	Benton.
	F	Fairfield.
	G	East Orland.

Table 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Maine—Continued.

No.	Operating company.	Station.
3321	Central Maine Power Co.—Continued.	
	H	Fairfield.
	J	Farmingdale.
	K	East Dover.
	L	Greenville.
	M	Burnham.
	N	Union Gas.
	P	Skowhegan.
	R	Do.
	T	Waterville.
	V	Oakland.
	W	Winslow.
	X	Rice Rips.
	Y	Skowhegan.
	AA	Brunswick.
3322	Cherryfield Electric Light Co	Cherryfield.
3323	Clark Power Co	Union Falls.
3324	Cornish & Kezar Falls Light & Power Co	Kezar Falls.
3325	Cumberland County Power & Light Co.:	
	A	Bonny Eagle.
	B	North Gorham.
	C	Bar Mills.
	D	West Buxton.
	E	Hiram.
	F	Forest Avenue.
	G	Plum Street.
3326	Danforth Electric Light Co	Danforth Village.
3327	Dennistown Power Co	Jackman.
3329	Easton Electric Co	Easton.
3330	Eastport Electric Light Co	Eastport.
3333	Farmington Power Co	Farmington.
3334	Fort Fairfield Light & Power Co	Fort Fairfield.
3336	Fort Kent Electric Co	Wallagrass.
3337	Franklin Light & Power Co	Anson.
3338	Fryeburg Electric Light Co	Fryeburg.
3339	Gould Electric Co	Presque Isle.
3340	Hartland Electric Light Co	Hartland.
3341	Houlton Water Co	Houlton.
35743	International Paper Co	Livermore Falls.
3343	Island Lighting Co	Island Falls.
3344	Vinalhaven Light & Power Co	Vinalhaven.
3346	Kingfield Light Co	Kingfield.
3347	Androscoggin & Kennebec Railway Co	Hallowell.
3348	Western Maine Power Co	Limerick.
3349	Limestone Light & Power Co	Limestone.
3376	Lincoln County Power Co.:	
	A	Damariscotta Mills.
	B	Bristol.
3350	Lisbon Falls Electric Co	Boston, Mass.
3351	Livermore Falls Light & Power Co	Livermore Falls.
3352	Washington County Light & Power Co	Machias, etc.
3354	Merrill Mill Co	Patten.
3355	Mallison Power Co	South Windham.
3354	Merrill Mill Co	Patten.
3356	Milo Electric Light & Power Co.:	
	A	Milo.
	B	Sebec.
3357	Monmouth Electric Co	Monmouth.
3358	Monson Light & Power Co	Monson.
3359	Monticello Electric Co	Monticello.
3360	G. H. Mooers	Ashland.
3361	Municipal electric plant	Bangor.
3363	do	Kennebunk.
3364	do	Lewiston.
3365	do	Madison.
3366	do	Newport.
3367	Oquossoc Light & Power Co	Kennebago Falls.
3368	Oxford Electric Co.:	
	A	Mechanic Falls.
	B	Norway.
	C	South Paris.
3370	Pennamaquam Power Co	Pembroke.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Maine—Continued.

No.	Operating company.	Station.
3373	Phillips Electric Light & Power Co	Phillips.
3376	Lincoln County Power Co	Damariscotta Mills, etc.
3377-1	Portsmouth, Dover & York Street Railway Co	Kittery Point.
3378	Presumpscot Electric Co.:	
	A	Dundee.
	B	Eel Weir.
	C	Saccarappa.
	D	Smelt Hill.
3379	Readfield Light & Power Co	Readfield.
3382	Rumford Falls Light & Water Co	Rumford.
3383	Rumford Falls Power Co	Do.
3385	Somerset Traction Co	Skowhegan.
3388	Stratton Electric Light Co	Eustis.
3389	Swan Falls Co	Fryeburg.
3390	C. A. Thompson & Co	New Sharon.
3391	Turner Light & Power Co	Turner.
3391-1	Turner Transformer Co	South Turner.
3392	Van Buren Light & Power district	Van Buren.
3344	Vinalhaven Light & Power Co	Vinalhaven.
3352	Washington County Light & Power Co.:	
	A	Machias.
	B	Pleasant River.
3348	Western Maine Power Co	Limerick.
3395	Westfield Electric Co	Westfield.
3396	A. George Weymouth	Farmington Falls.
3397	Wilton Light Co	Wilton.
35799	Wing Spool & Bobbin Co	Kingfield.
3400	Winthrop & Wayne Light & Power Co	Winthrop.
3401	Wiscasset Electric Light & Power Co	Wiscasset.
3403	Yarmouth Lighting Co	Yarmouth.
3404	York County Power Co.:	
	A	Biddeford.
	B	Sanford.
35743	International Paper Co	Livermore Falls.
35799	Wing Spool & Bobbin Co	Kingfield.

Maryland.

3500	Annapolis Public Utilities Co	Annapolis.
3501	Antietam Electric Light & Power Co	Breathedsville.
3502	Baltimore County Electric Co	Baltimore.
3504	Baltimore, Halethorpe & Elkridge Railway Co	Do.
3505	Baltimore, Sparrows Point & Chesapeake Railway Co	Do.
3506	Baltimore & Bel Air Electric Railway Co	Bel Air.
3508	Bel Air Electric Co.:	
	A	Bel Air No. 1.
	B	Bel Air No. 2.
3509	E. A. C. Bucky	Union Bridge.
3510-1	Capital Traction Co	Chevy Chase.
3511	Chestertown Electric Light & Power Co	Chestertown.
3513	Consolidated Gas, Electric Light & Power Co.:	
	A	Ilchester.
	C	Westport.
3514	Consolidated Public Utilities Co	Westminster.
3513	Consumers Ice Co	Crisfield.
3516	Cumberland Electric Railway Co	Cumberland.
3517	Cumberland & Westernport Electric Railway Co.:	
	A	Clarysville.
	B	Reynolds.
3518	Delmarvia Utilities Co	Ocean City.
3519	Eastern Shore Gas & Electric Co.:	
	A	Denton (hydroelectric).
	B	Salisbury.
	C	Denton (steam).
3520	Edison Electric Illuminating Co	Cumberland.
3521	Electric Ice Manufacturing Co	Pocomoke City.
3522	Elkton Electric Light & Power Co	Elkton.
3523	Emmitsburg Electric Co	Emmitsburg.
3524	Gilpins Falls Electric Co	Gilpins Falls.
3525	Hagerstown & Frederick Railway Co	Security.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Maryland—Continued.

No.	Operating company.	Station.
3526	Havre de Grace Electric Co	Havre de Grace.
3526-1	Hillsboro Lighting Co	Hillsboro.
3527	Home Electric Light Co	Lonaconing.
3528	Home Manufacturing Light & Power Co	Elkton.
3530	Kensington Railway Co. & Sandy Spring Railway Co	Kensington.
3531	Lorraine Electric Railway	Baltimore.
3532	Maryland Electric Railways Co	Annapolis.
3533	Midland Electric Light Co	Midland.
3534	Mountain Lake Park Association	Mountain Lake Park.
3535	Mount Washington Electric Light & Power Co	Baltimore.
3536	Municipal electric plant	Aberdeen.
3537	do	Berlin.
3538	do	Centerville.
3540	do	Easton.
3541	do	Frederick.
3542	do	Hagerstown.
3543	do	Laurel.
3543-1	do	Queenstown.
3543-2	do	Rock Hall.
3544	do	Williamsport.
3545	New Windsor Electric Light & Water Co	New Windsor.
3545-1	Northern Maryland Electric Co	Oxford, Pa.
3546	Oakland Electric Co	Oakland.
3549	Perryville Electric Co	Perryville.
3550	Port Deposit Electric Co	Port Deposit.
3551	Princess Anne Electric Plant	Princess Anne.
3552	St. Michaels Utilities Commission	St. Michaels.
3555	Snow Hill Electric Light & Power Co	Snow Hill.
3551-1	Stockton Electric Light Co	Stockton.
3557	Towson & Cockeysville Electric Railway Co	Bel Air.
3558	Union Bridge Electric Manufacturing Co	Union Bridge.
3559	United Railways & Electric Co.:	
	C	Owings Mills, Baltimore.
	D	Pratt Street, Baltimore.
3560	Washington, Baltimore & Annapolis Electric Railroad Co	Baltimore.

Massachusetts.

No.	Operating company.	Station.
3601	Agawam Electric Co	Springfield.
3602	American Woolen Co	Maynard.
3603	Amesbury Electric Light Co	Amesbury.
3604	Amherst Gas Co	Amherst.
3605	Athol Gas & Electric Co.:	
	A	Athol.
	B	Wendell Depot.
	C	Farley.
3607	Attleboro Steam & Electric Co	Attleboro.
3608	Ayer Electric Light Co	Ayer.
3609	Eastern Massachusetts Street Railway Co	Byfield, etc.
3610	Berkshire Street Railway Co.:	
	A	Pittsfield.
	B	Zylonite.
3611	Beverly Gas & Electric Co	Beverly.
3612	Blackstone Electric Light Co	Blackstone.
3614	Blue Hill Street Railroad Co	Canton.
3616	Boston Elevated Railway Co.:	
	A	Central.
	B	Charlestown.
	C	Dorchester.
	D	Cambridge.
	E	Lincoln.
	F	South Boston.
3618	Boston & Worcester Street Railroad Co	Framingham.
3620	Brockton & Plymouth Street Railway Co	Plymouth.
3621	Buzzards Bay Electric Co	Falmouth.
3622	Cambridge Electric Light Co	Cambridge.
37440-1	Cape Cod Cold Storage Co	Provincetown.
3623	Central Massachusetts Electric Co	Blanchardville.
3626	Charlemont Electric Light & Power Co	Charlemont.
3627	Charlestown Gas & Electric Co	Charlestown.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Massachusetts—Continued.

No.	Operating company.	Station.
3628	Chester Electric Light Co	Chester.
3629	Citizens Gas, Electric Light & Power Co	Nantucket.
3630	Clinton Gas Light Co	Clinton.
3631	Concord, Maynard & Hudson Street Railroad Co	Maynard.
3633	Conway Electric Street Railway Co	Conway.
3633-1	Eastern Massachusetts Electric Co	Boston.
3609	Eastern Massachusetts Street Railway Co.:	
	A	Byfield.
	B	Chelsea.
	C	Essex Falls.
	D	Gloucester.
	E	Haverhill.
	F	Hyde Park.
	H	Lawrence.
	J	Quincy.
	K	Lynn.
	L	Salem.
	M	Woburn.
	N	Lowell.
3634	Easthampton Gas Co	Montague City.
3636	Edison Electric Illuminating Co. of Boston:	
	A	South Boston.
	D	Atlantic Avenue.
3637	Edison Electric Illuminating Co. of Brockton	East Bridgewater.
3638	Electric Light & Power Co. of Abington and Rockland	North Abington.
3639	Fall River Electric Light Co	Fall River.
3640	Fitchburg Gas & Electric Light Co	Fitchburg.
3641	Fitchburg & Leominster Street Railway Co.:	
	A	Do.
	B	Do.
3642	Franklin Electric Light Co	Turners Falls.
3643	Gardner Electric Light Co	Gardner.
3644	Gloucester Electric Co	Gloucester.
3646	Greenfield Electric Light & Power Co.:	
	A	Greenfield.
	B	Gardner Falls.
3648	Haverhill Electric Co	Haverhill.
3649	Holyoke Street Railway Co	Holyoke.
3950	Holyoke Water Power Co	Do.
3651	Huntington Electric Light Co	Huntington.
3653	Interstate Consolidated Street Railway Co	Springfield.
3655	Lawrence Gas Co	Lawrence.
3656	Lee Electric Co	Lee.
3658	Leominster Electric Light & Power Co	Leominster.
3660	Lowell Electric Light Corporation	Lowell.
3662	Ludlow Electric Light Co	Ludlow.
3664	Lynn Gas & Electric Co	Lynn.
3665	Malden Electric Co	Malden.
3666	Manchester Electric Co	Manchester.
3667	Marlboro Electric Co	Marlboro.
3669	Merrimac Valley Building & Power Co	Amesbury.
3669-1	Metropolitan District Commission:	
	A	Wachusett.
	B	Sudbury.
3671	Middletown Electric Light Co	Middletown.
3672	Milford, Attleboro & Woonsocket Street Railway Co	Unionville.
3673	Milford Electric Light & Power Co	Boston.
3675	Mill River Electric Co	Williamsburg.
3676	Monument Mills:	
	A	Stockbridge No. 1.
	B	Stockbridge No. 2.
3677	Municipal electric plant	Ashburnham.
3678	.....do	Belmont.
3679	.....do	Boylston Center.
3681	.....do	Chicopee.
3682	.....do	Concord.
3683	.....do	Danvers.
3684	.....do	East Braintree.
3684-1	.....do	Georgetown.
3685	Pepperell Electric Light & Power Co	East Pepperell.
3686	Municipal electric plant	Groton.
3687	.....do	Groveland.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Massachusetts—Continued.

No.	Operating company.	Station.
3688	Municipal electric plant	Hingham.
3689	.....do	Holden.
3690	.....do	Holyoke.
3691	.....do	Hudson.
3692	.....do	Hull.
3693	.....do	Ipswich.
3694	.....do	Littleton.
3695	.....do	Lunenburg.
3696	.....do	Mansfield.
3697	.....do	Marblehead.
3698	.....do	Merrimac.
3699	.....do	Middleboro.
3700	.....do	North Attleboro.
3725	.....do	North Dana.
3701	.....do	Norwood.
3702	.....do	Peabody.
3704	.....do	Reading.
3705	.....do	Rowley.
3706	.....do	Shrewsbury.
3707	.....do	South Hadley.
3708	.....do	Sterling.
3709	.....do	Taunton.
3710	.....do	Templeton.
3711	.....do	Wakefield.
3712	.....do	Wellesley.
3713	.....do	West Boylston.
3714	.....do	Westfield.
3717	New Bedford Gas & Edison Light Co	New Bedford.
3719	Newburyport Gas & Electric Co	Newburyport.
3720	New England Power Co.:	
	A	Deerfield No. 5.
	B	Deerfield No. 2.
	C	Deerfield No. 3.
	D	Deerfield No. 4.
	E	Fitchburg.
	F	Uxbridge.
3721	Norfolk & Bristol Street Railway Co	South Walpole.
3722	North Adams Gas Light Co	North Adams.
3723	Northampton Electric Lighting Co	Northampton.
3724	Northampton Street Railway Co	Do.
3725	Municipal electric plant	North Dana.
3727	Norton Power & Electric Co	Chartley.
3729	Norton, Taunton & Attleboro Street Railway Co	Norton.
3685	Pepperell Electric Light & Power Co	East Pepperell.
3734	Pittsfield Electric Co.:	
	A	Silver Lake.
	B	Pittsfield.
3735	Plymouth Electric Light Co	Plymouth.
3739	Provincetown Light & Power Co	Provincetown.
3740	Quincy Electric Light & Power Co	Quincy.
3741	Randolph & Holbrook Power & Electric Co	Randolph.
3742	Salem Electric Lighting Co	Salem.
3743	Seekonk Electric Co	Seekonk.
3744	Shelburne Falls & Colerain Street Railway Co	Shelburne Falls.
3745	Shirley Electric Co	Shirley.
3746	Southeastern Massachusetts Power & Electric Co	Marion.
3747	Spencer Gas Co	Spencer.
3749	Southern Berkshire Power & Electric Co	Great Barrington.
3751	Suburban Gas & Electric Co	Revere.
3752	Sunderland Electric Light & Power Co	Sunderland.
3755	Turners Falls Power & Electric Co.:	
	A	Hampden.
	B	Turners Falls.
	C	Cabot.
3756	Tyngsboro Electric Light Co	Tyngsboro.
3757	Union Light & Power Co	Franklin.
3758	Union Street Railway Co	New Bedford.
3759	United Electric Light Co.:	
	A	Indian Orchard.
	B	Bircham Bend.
	C	Springfield.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Massachusetts—Continued.

No.	Operating company.	Station.
3760	Vineyard Lighting Co.:	
	A	Vineyard Haven.
	B	Oak Bluffs.
3761	Ware Electric Co	Ware.
3764	Webster & Southbridge Gas & Electric Co	Webster.
3764-1	Westfield Power Co	Westfield.
3765	Weymouth Light & Power Co	East Weymouth.
3766	Williamstown Gas Co	Williamstown.
3767	Winchendon Electric Light & Power Co	Winchendon.
3768	Worcester Consolidated Street Railway Co.:	
	B	Leominster.
	C	Milbury.
	D	Northboro.
	E	West Berlin.
3769	Worcester Electric Light Co	Webster Street.
3770	Worcester Suburban Electric Co	Uxbridge.
37440-1	Cape Cod Cold Storage Co	Provincetown.

New Hampshire.

No.	Operating company.	Station.
5400	William F. Allen Light Co	West Stewartstown.
5401	Alton Electric Light & Power Co	Alton.
5402	Antrim-Bennington Electric Light & Power Co.:	
	A	Antrim.
	B	Bennington.
5403	Municipal Electric Commission	Ashland.
5404	Berlin Street Railway Co	Gorham.
5405	Bethlehem Electric Co	Bethlehem.
5406	*See* Concord Electric Railways	Franklin, etc.
5407	Bradford Light & Power Co	Bradford.
5408	Bristol Electric Light Co	Bristol.
5410	Canaan & Enfield Electric Co	Raymond.
5412	Vermont Hydro Electric Corporation	Claremont.
5414	Cloutman Gas & Electric Co	Farmington.
5415	Concord Electric Co	Sewalls Falls.
5406	Concord Electric Railways:	
	A	Franklin.
	B	West Concord.
5416	Contoocook Electric Light Co	Davisville.
5417	Conway Electric Light & Power Co	Center Conway.
5418	Derry Electric Co	Derry.
5422	Exeter & Hampton Electric Co	Exeter.
5423	O. D. Fessenden	South Brookline.
5424	Franklin Light & Power Co.:	
	A	Franklin.
	B	Salmon Brook.
5425	Goodrich Falls Electric Co	Goodrich Falls.
5425-1	Grafton County Electric Light & Power Co.:	
	A	West Lebanon.
	B	Lebanon.
	C	West Lebanon.
5426	Greenville Electric Lighting Co	Greenville.
5427	Groveton Electric Light Co	Groveton.
5429	Hillsboro Electric Light & Power Co	Hillsboro.
5430	Hollis Electric Light Co	Hollis.
5431	Jones & Linscott Electric Co	Lancaster.
5432	Keene Gas & Electric Co.:	
	A	Swanzey.
	B	Do.
	C	Dublin.
	D	Peterboro.
	E	Marlboro.
5433	Laconia Gas & Electric Co.:	
	A	Lochmere.
	B	Lakeport.
5435	Lisbon Light & Power Co.:	
	A	Lisbon.
	B	Bath.
	C	Lisbon.

TABLE 100.—*Electro-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

New Hampshire—Continued.

No.	Operating company.	Station.
5437	Manchester Traction, Light & Power Co.:	
	A.	Brook Street.
	C.	Garvin Falls.
	D.	Greggs Falls.
	E.	Hooksett.
	F.	Kelleys Falls.
	G.	Nashua.
5442	Meredith Electric Light Co.	Meredith.
5443	Milford Light & Power Co.	Milford.
5403	Municipal Electric Commission.	Ashland.
5444	Municipal electric plant.	Littleton.
5445	do.	Wolfeboro.
5447	New Hampshire Water & Electric Power Co.	Fitzwilliam.
5448	New Hampton Electric Light & Power Co.	New Hampton.
5450	Newport Electric Light Co.:	
	A.	Newport.
	B.	North Newport.
46459-1	Parker Young Co.:	
	A.	Lincoln.
	B.	Do.
5454	Pittsfield Light & Power Co.	Pittsfield.
5455	Plymouth Electric Light Co.	Plymouth.
5457	Raymond Electric Co.	Raymond.
5458	Rockingham County Light & Power Co.:	
	A.	Portsmouth.
	B.	Durham.
5458-1	Rumney Electric Co.	Rumney.
5459	Salem Electric Light Co.	North Salem.
5462	Sunapee Electric Light & Power Co.	Sunapee.
5463	Tilton Electric Light & Power Co.	Tilton.
5465	Twin State Gas & Electric Co.:	
	A.	Dover.
	B.	Gorham.
	C.	Milton.
5412	Vermont Hydro Electric Corporation.	Claremont.
5468	Wentworth-Hall Electric Co.	Jackson.
5469	West Campton Electric Light Co.	West Campton.
5470	Whitefield Electric Light Co.	Whitefield.
5471	Wonalancet Electric Co.	Wonalancet.
5472	Woodsville Aqueduct Corporation.	Woodsville.
46459-1	Parker Young Co.	Lincoln.

New Jersey.

No.	Operating company.	Station.
5500	Atlantic City Electric Co.:	
	A.	Atlantic City.
	B.	Ocean City.
	C.	Pleasantville.
5502	Atlantic City & Shore Railroad Co.	Atlantic City.
5503	Atlantic Coast Electric Light Co.	Asbury Park.
5504	Atlantic Coast Electric Railway Co.	Allenhurst.
5505	Atlantic County Electric Co.	Egg Harbor.
5506	Atlantic & Suburban Railway Co.	Pleasantville.
5506-1	Barnegat Light & Power Co.	Seaside Heights.
5507	Blair Electric Light Co.	Blairstown.
5508	Boonton Electric Co.	Boonton.
5509	Branchville Electric Power, Water & Lighting Co.	Branchville.
5511	Bridgeton & Millville Traction Co.	Bridgeton.
5513	Burlington County Transit Co.	Hainesport.
5514	Califon Electric Light & Power Co.	Califon.
5593	Cape May Court House Light & Water Co.	Cape May Court House
5515	Cape May Light & Power Co.	Cape May.
5517	Central Passenger Railway Co.	Atlantic City.
5594	E. R. Collins & Son:	
	A.	Market Street, Belvidere.
	B.	South Water Street, Belvidere.
5519	Commonwealth Electric Co.	Summit.
5520	Consolidated Gas Co. of New Jersey	Long Branch.
5522	Pennsylvania Utilities Co.	Columbia.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

New Jersey—Continued.

No.	Operating company.	Station.
5523	Electric Co. of New Jersey:	
	A	Salem.
	B	Bridgeton.
5524	Electric Light & Power Co	Hightstown.
5524 -1	Eureka Power Co	Trenton.
5525	Five Mile Beach Electric Railway Co	Camden.
5526	Flemington Electric Light, Heat & Power Co	Flemington.
5527	Hackettstown Electric Light Co	Hackettstown.
5528	Hammonton & Egg Harbor City Gas Co	Hammonton.
5529	Harrison Heights Improvement Co	Mullica Hill.
5530	Hoboken Shore Road	Hoboken.
5531	Hunterdon Electric & Power Co	High Bridge.
5533	Jamesburg Electric Co	Jamesburg.
5534	Jersey Central Traction Co	Keyport.
5536	Jersey Electric Co	High Bridge.
5536-1	J. C. Kennedy Electric Co	Long Valley.
5537	Lakewood & Coast Electric Co	Lakewood.
5538	Lambertville Public Service Co	Lambertville.
5540	Millburn Electric Co	Millburn.
5541	Millville Electric Light Co.:	
	A	Sharp Street.
	B	Second Street.
47543	Millville Manufacturing Co	Millville.
5542	Millville Traction Co	Do.
5543	Monmouth County Electric Co	Red Bank.
5544	Monmouth Lighting Co	Keyport.
5546	Morris County Traction Co	Morristown.
5547	Morris Railroad Co	Do.
5548	Morris & Somerset Electric Co	Do.
5549	Municipal electric plant	Allentown.
5550	do	Andover.
5551	do	Atlantic Highlands.
5525	do	Butler.
5553	do	Chatham.
5554	do	Frenchtown.
5555	do	Madison.
5556	do	Orange.
5557	do	Park Ridge.
5557-1	do	Pompton Lakes.
5558	do	Seaside Park.
5559	do	South River.
5560	do	Vineland.
5561	New Egypt Light, Heat, Power & Water Co	New Egypt.
5562	New Jersey Power & Light Co.:	
	C	Dover.
	D	Boonton.
5564	New Jersey & Pennsylvania Traction Co	Trenton.
5565	New Jersey Water & Light Co	Deal Beach.
5565-1	New York Edison Co	Jersey City power house.
5566	Newton Gas & Electric Co	Newton.
5566-1	Northampton, Easton & Washington Traction Co	Port Colden.
5567	North Jersey Rapid Transit Co	Paterson.
5568	Ocean City Electric Railroad Co	Ocean City.
5569	Ocean Grove Camp Meeting	Bradley Beach.
5522	Pennsylvania Utilities Co	Columbia.
5571	Phillipsburg Transit Co	Phillipsburg.
5575	Public Service Electric Co.:	
	A	Edgewater.
	B	Metuchen.
	D	Buckingham Avenue.
	E	Red Bank.
	F	City dock, Newark.
	G	Coal Street, Newark.
	H	Hoboken.
	I	Marion (Jersey City).
	J	Paterson.
	K	Camden.
	L	Burlington.
	N	Plainsboro.
	O	Trenton.
	P	Cranford.
	R	Secaucus.
	S	Essex.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

New Jersey—Continued.

No.	Operating company.	Station.
5576	Public Service Railway Co.	Newark.
5577	Rockland Electric Co. of New Jersey	Gloucester.
47551	Sayre & Fisher Co.	Sayreville.
5580	Sayreville Electric Light & Power Co.	Do.
5581	Seacoast Traction Co.	Seagirt.
5582	Sea Isle City Electric Light, Power & Water Co.	Sea Isle City.
5584	Stone Harbor Electric Light & Power Co.	Stone Harbor.
5587	Toms River Electric Co.	Toms River.
5588	Trenton, Lakewood & Seacoast Railway	Trenton.
5589	Trenton, Lawrenceville & Princeton Railroad Co.	Do.
5590	Trenton & Mercer Co. Traction Corporation	Do.
5591	Trenton Street Railway Co.	Do.
5598	Vulcan Power Co.	Netcong.
5593	Cape May Court House Light & Water Co.	Cape May Court House.
5594	E. R. Collins & Son:	
	A	Market Street, Belvidere.
	B	South Water Street, Belvidere.
5595	Washington Electric Co.	Washington.
5596	West Jersey Electric Co.	Wildwood.
5597	West Jersey & Seashore Railroad Co.	Westville.
5598	Vulcan Power Co.	Netcong.
5600	Woodbine Land & Improvement Co.	Woodbine.
5601	Woodbourne Electric Light, Heat & Power Co.	Woodbourne.
47543	Millville Manufacturing Co.	Millville.
47551	Sayre & Fisher Co.	Sayreville.

New York.

No.	Operating company.	Station.
5800	Adams Electric Light Co.	Adams.
5801	Addison Electric Light & Power Co.	Addison.
6180	Adirondack Power & Light Corporation:	
	A	Johnsonville.
	B	Schaghticoke.
	C	East Creek.
	D	Inghams Mills.
	E	Mechanicsville.
	F	Schoharie Falls.
	G	Spier Falls.
	H	Utica.
	J	Kanes Falls.
	K	North Granville.
	L	Granville.
5804	Adrian Knitting Co.	Sanquoit.
5805	Afton-Windsor Light, Heat & Power Co. (Inc.)	Center Village.
5806	Albany Southern Railroad Co.	Stuyvesant Falls.
5807	Antwerp Light & Power Co.	Antwerp.
5809	Atlantic Light & Power Co.	Coeymans.
5811	Auburn & Syracuse Electric Railroad	Syracuse.
5812	Aurora Electric Light Co.	Aurora.
5813	Ausable Valley Light, Heat & Power Co.	Keene.
5814	Avon Electric Co.	Avon.
5817	Batavia Traction Co.	Batavia.
5946	Berkshire Street Railway Co.	Walloomsac.
5821	Berlin Electric Light, Heat & Power Co.	Berlin.
5822	Binghamton Light, Heat & Power Co.:	
	A	Binghamton.
	B	Johnson City.
5823	Binghamton Railway Co.	Binghamton.
5824	Black River Traction Co.	Watertown.
5825–1	Bombay Electric Corporation	Bombay.
5826	Boquet Electric Power Co.	Essex.
5827	Broadalbin Electric Light & Power Co.	Broadalbin.
5828	Bronx Gas & Electric Co.	Bronx.
5893	Brooklyn Edison Co.	Gold Street.
5832	Brooklyn Rapid Transit Co.:	
	A	Central Power.
	B	Williamsburg.
	C	Ninth Street.
5833	Bryant Power Co. (Inc.)	Buffalo.
5834	Buffalo General Electric Co.	Do.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

New York—Continued.

No.	Operating company.	Station.
5835	Rochester, Lockport & Buffalo Railroad Corporation	Rochester.
5836	Buffalo & Depew Railway Co	Buffalo.
5839	Buffalo & Williamsville Electric Railway Co	Williamsville.
5840	Buffalo Southern Railway Co	Ebenezer.
5842	Callicoon Independent Electric Co. (Inc.)	Callicoon.
5843	Canaseraga Heat, Light & Power Co	Canaseraga.
5843–1	Canisteo Light & Power Co	Canisteo.
5844	Canton Electric Light & Power Co	Canton.
5846	Cattaraugus Electric Light & Power Co	Cattaraugus.
5847	Cayadutta Generating Co	Berryville.
5847–1	Cayuga Power Corporation	Portland Point.
5848	Cazenovia Electric Co	Cazenovia.
5849	Central Hudson Gas & Electric Co.:	
	A	Newburgh.
	B	Poughkeepsie.
5851	Central New York Power Co	Canastota.
5853	Champlain Electric Co	Champlain.
5854	Chasm Power Co	Chateaugay.
5855	Chautauqua Traction Co	Jamestown.
5856	Chatham Electric Light, Heat & Power Co	Chatham.
48834	A. C. Cheney Piano Action Co	Castleton.
5858	Clinton Hematite Mines	Clinton.
5858–1	Clymer Power Corporation	Clymer.
5859	Cohoes Power & Light Corporation	Cohoes.
5862	Cold Spring Light, Heat & Power Co	Cold Spring.
5863	College Hill Electric Light Co	Clinton.
5867	Consolidated Electric Co	Middle Falls.
5868	Consolidated Light & Power Co	Whitehall.
5868–1	Consumers Gas Co	Southampton.
5869	Corinth Electric Light & Power Co	Corinth.
5869–1	Corning Light & Power Corporation	Corning.
5871	Cortland County Traction Co	Cortland.
5873	Croton Falls Electric Light Plant	Croton Falls.
5874	Dansville Gas & Electric Co	Dansville.
5875	Deansboro Electric Light Plant	Deansboro.
5876	Deer River Power Co	Copenhagen.
5877	Delaware County Electric Light & Power Co	Delhi.
5878	Delaware & Otsego Light & Power Co	Franklin.
5879	Depew & Lancaster Light, Power & Conduit Co	Lancaster.
5882	Dundee Electric Lighting Plant	Dundee.
50256–1	John Dunlop's Sons	Phoenix.
5885	Dutchess Light, Heat & Power Co	Rhinebeck.
5886	Dwaas Electric Co	Hudson Falls.
5887	Earlville Electric Light Co	Earlville.
5888	East Aurora Electric Light Co	East Aurora.
5891	East Hampton Electric Light Co	East Hampton
5892	Eaton-Morrisville Power Co.:	
	A	Eaton.
	B	Morrisville.
5893	Brooklyn Edison Co	Gold Street.
5895	Edwards Light & Power Co	Edwards.
5896	Electric Light Co. of Newpaltz	Newpaltz.
5897	Elizabethtown Electric Plant	Elizabethtown.
5898	Ellenville Electric Co	Ellenville.
5900	Elmira, Corning & Waverly Railroad	Elmira.
5901	Elmira Water, Light & Railroad Co	Do.
5903	Empire Gas & Electric Co.:	
	A	Auburn.
	B	Geneva.
	C	Lyons.
	D	Newark.
	E	Waterloo.
	F	Seneca Falls.
5904	Empire State Railroad Corporation	Oswego.
5905	Erie Railroad Co	Rochester.
5906	Falconer Electric Light Co	Falconer.
49143	Endicott, Johnson & Co	Johnson City.
5907	W. H. Faxon Electric Plant	Chestertown.
5908	Fishers Island Electric Light & Power Co	Fishers Island.
5909	Fishkill Electric Railway Co	Bacon.
5910	Flatbush Gas Co	Brooklyn.
5911	Fonda, Johnstown & Gloversville Railroad	Tribes Hill.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

New York—Continued.

No.	Operating company.	Station.
5912	Forestport Electric Light Plant	Forestport.
5913	Fort Covington Light, Heat & Power Co	Fort Covington.
5914	Fort Plain Gas & Electric Light, Heat & Power Co	Fort Plain.
5916	Franklin Springs & Progressive Electric Light Co	Franklin Springs.
5917	Fulton Chain Electric Co	Fulton Chain.
5918	Fulton County Gas & Electric Co.:	
	A	Gloversville.
	B	Samonsville.
5919	Fulton Light Heat & Power Co	Fulton.
5920	Garden City Co	Garden City.
5921	Garner Print Works & Bleachery	Wappingers Falls.
49275	General Electric Co	Schenectady.
5922	Genesee Light & Power Co	Batavia.
5923	Genesee Valley Power Co	Mills Mills.
5924	Geneseo Gas Light Co	Geneseo.
5925	Geneva, Seneca Falls & Auburn Railroad Co. (Inc.)	Seneca Falls.
5926	G. N. Gibson & Sons	West Stockholm.
5927	Glen Cove Light & Power Co	Glen Cove.
5929	Glens Falls Gas & Electric Light Co	Glens Falls.
5930	Goshen Light & Power Co	Monroe.
49320	Gould Paper Co	Lyons Falls.
5932	Granville Electric & Gas Co	Granville.
5933	Great Bear Light & Power Co	East Worcester.
5934	Gregory Electric Co. (Inc.)	Morristown.
6041	Groton Electric Power Corporation	Groton.
5935	Halfmoon Light, Heat & Power Co	Mechanicsville.
5936	E. S. Hamblin & Co	Oriskany Falls.
5937	Hammondsport Electric Light Co	Hammondsport.
5938	Hanford Bros	East Meredith.
5939	Hannawa Falls Water Power Co	Hannawa Falls.
5940	Harlem Valley Light, Heat & Power Co	Pawling.
5942	Hermon Electric Co	Hermon.
5943	Hilton Electric Light, Power & Heat Co	Hilton.
5944	Holmes Milling Co	Downsville.
5945	Honk Falls Power Co.:	
	A	Napanoch.
	B	High Falls.
5946	Berkshire Street Railway Co	Walloomsac.
5947	Hornell Electric Co	Hornell.
5950	Hudson Valley Railway Co.:	
	A	Middle Falls.
	B	Stillwater.
	C	Mechanicsville.
5951	Hudson & Manhattan Railroad Co	Terminal Building.
6164	Alfred Huntington	Ripley.
5954	Hydro Electric Power Co	Theresa.
5955	Interborough Rapid Transit Co.:	
	A	East River.
	B	North River.
5957	International Railway Co	Niagara Street, Buffalo.
5960	New York State Gas & Electric Corporation	Oneonta.
6159	Iroquois Utilities (Inc.)	Randolph.
5961	Ithaca Traction Co	Ithaca.
5962	Jamestown Lighting & Power Co	Jamestown.
5963	Jamestown Street Railway Co	Do.
5964	Jamestown, Westfield & North-Western Railroad Co	Do.
5965	Jordan Electric Light & Power Co	Jordan.
5968	Katonah Lighting Co	Bedford Hills.
5970	Kingston Consolidated Railroad Co	Kingston.
5971	Kingston Gas & Electric Co	Do.
5972	Edward R. Ladew Co. (Inc.)	Glen Cove.
5973	La Fargeville Electric Light Co	La Fargeville.
5974	Lake Shore Electric Co	Henderson.
6205	La Salle Electric Corporation	Niagara Falls.
5975	Lawrence Park Heat, Light & Power Co	Bronxville.
5976	Lebanon Valley Lighting Co. (Inc.)	Canaan.
5977	Le Roy Hydraulic Electric Gas Co	Le Roy.
5979	Lewiston & Lake Ontario Shore Power Co	Lewiston.
5981	Liberty Light & Power Co	Liberty.
5983	Livingston Manor Electric Co	Livingston Manor.
5984	Livingston-Niagara Power Co	Avon.
5985	Livonia Light & Heat Co	Whiting.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

New York—Continued.

No.	Operating company.	Station.
5986	Lockport Light, Heat & Power Co.:	
	A	Race Street.
	B	Elm Street.
5987	Long Acre Electric Light & Power Co	103 Park Avenue, New York.
5988	Long Beach Power Co	Long Beach.
5990	Long Island Lighting Co.:	
	A	Amityville.
	B	Babylon.
	D	Northport.
	E	Sayville.
	F	Bay Shore.
	G	Huntington.
	H	Port Jefferson.
	J	Do.
5992	Lyons Falls Electric Light Plant	Lyons Falls.
5993	Macedon Electric Light Co	Macedon.
5994	Madrid Electric Light Co	Madrid.
5995	Malone Light & Power Co.:	
	A	High Falls.
	B	Do.
	C	Malone.
	D	Chasm Falls.
	E	Whittlesey.
5998	Marcellus Lighting Plant	Marcellus.
6000	Marion Power Co	Sodus.
6001	Massena Electric Light & Power Co	Potsdam.
6003	Mexico Electric Co	Mexico.
6005	Middleville Electric Light Co	Frisbieville.
6006	.....do	Middleville.
6006-1	Middleport Gas & Electric Light Co	Middleport.
6007	Millerton Electric Light Co	Millerton.
6008	Milling & Lighting Co	Brasher Falls.
6009	Mineville Light, Heat & Power Co	Mineville.
6010	Mohawk Hydro Electric Co	Ephrata.
6012	Montgomery Electric Light & Power Co	Canajoharie.
6013	Mooers Electric Light Co	Mooers.
6014	Moravia Electric Light, Heat & Power Co	Moravia.
6015	Morgan & Wyman Light & Power Co	Dover Plains.
6017	Mount Morris Illuminating Co	Mount Morris.
6018	Municipal electric plant	Akron.
6019	.....do	Arcade.
6021	.....do	Batavia.
6022	.....do	Bath.
6023	.....do	Bergen.
6024	.....do	Boonville.
6025	.....do	Brockton.
6026	.....do	Camden.
6028	.....do	Castile.
6029	.....do	Clifton Springs.
6030	.....do	Clinton.
6031	.....do	Delevan.
6033	.....do	Dunkirk.
6034	.....do	Fairport.
6035	.....do	Frankfort.
6036	.....do	Fredonia.
6037	.....do	Freeport.
6038	.....do	Greene.
6039	.....do	Green Island.
6040	.....do	Greenport.
6041	Groton Electric Power Corporation	Groton.
6043	Municipal electric plant	Hamilton.
6044	.....do	Herkimer.
6045	.....do	Holley.
6046	.....do	Ilion.
6047	.....do	Jamestown.
6048	.....do	Lake Placid.
6049	.....do	Little Valley.
6050	.....do	Marathon.
6051	.....do	Mayville.
6053	.....do	Mohawk.
6054	.....do	Newark Valley.
6056	.....do	Penn Yan.

Table 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

New York—Continued.

No.	Operating company.	Station.
6057	Municipal electric plant	Philadelphia.
6058	do	Port Byron.
6059	do	Potsdam.
6060	do	Rockville Center.
6061	do	Rouses Point.
6062	do	Salamanca.
6063	do	Savannah.
6064	do	Sherburne.
6065	do	Silver Springs.
6066	do	Skaneateles.
6067	do	Solvay.
6069	do	Springville.
6070	do	Theresa.
6071	do	Tully.
6072	do	Tupper Lake.
6073	do	Union.
6074	do	Watkins.
6075	do	Wellsville.
6076	do	Westfield.
6078	Municipal Gas Co	Albany.
6079	Murray Electric Light & Power Co	Monticello.
6081	Nassau Light & Power Co	Glenwood.
6083	New Berlin Light & Power Co	New Berlin.
50074-1	New Fabric Cloth Co	Oswego.
6084	Newfane Electric Co	Newfane.
50074	Newfane Lumber & Manufacturing Co	Do.
6085	New Paltz Highland & Poughkeepsie Traction Co	Loyd.
6086	Newport Electric Light & Power Co	Newport.
6087	New York Central Railroad:	
	A	Glenwood.
	B	Port Morris.
6090	New York Edison Co.:	
	A	Duane Street.
	B	Waterside No. 1.
	C	Waterside No. 2.
	D	Kingsbridge.
5960	New York State Gas & Electric Corporation:	
	A	Ithaca.
	B	Norwich.
	C	Oneonta.
6093	New York State Railways, Rochester Lines:	
	A	Floatbridge.
	B	Canandaigua.
6097	New York & Long Island Traction Co	Rockville Center.
6098	New York & North Shore Traction Co	Douglaston.
6099	New York & Ontario Power Co	Waddington.
6101	New York & Queens Electric Light & Power Co	Astoria.
6103	Niagara Electric Service Corporation	Niagara Falls.
6105	Niagara Falls Gas & Electric Light Co	Do.
6106	Niagara Falls Power Co.:	
	A	Do.
	B	Hydraulic.
6108	Niagara, Lockport & Ontario Power Co.:	
	A	Salmon River.
	B	Auburn.
	C	Lyons.
	D	Minetto.
6109	Niagara & Erie Power Co	Buffalo.
6110	North Creek Electric Co	North Creek.
6111	Northern Adirondack Power Co	Ausable Chasm.
6112	Northern New York Utilities:	
	A	Black River.
	B	Effley Falls.
	C	Elmer Falls.
	D	South Edwards.
	E	Taylorville.
	F	Watertown.
	G	Belfort.
	H	Browns Falls.
6113	Northern Wayne Electric Light & Power Co	Wolcott.
6114	Northern Westchester Lighting Co	Ossining.
6116	North Syracuse Light & Power Co	North Syracuse.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

New York—Continued.

No.	Operating company.	Station.
6118	Norwood Electric Light & Power Co.	Yaleville.
6118-1	Nuerd Paper Co. (Inc.)	Hadley.
6119	Nunda Electric Light Co.	Nunda.
6121	Ogdensburg Power & Light Co.	Ogdensburg.
6123	Olean Electric Light & Power Co.:	
	A	Franklinville.
	B	Olean.
6175	O'Neil & Co.	St. Regis Falls.
6126	Orange County Public Service Corporation:	
	A	Cuddebackville.
	B	Middletown.
	C	Port Jervis.
6127	Orange County Traction Co.	Newburgh.
6128	Orange & Rockland Electric Co.	Monroe.
6129	B. L. Orcutt & Sons (Inc.)	Dickinson Center.
6130	Oswegatchie Light & Power Co.:	
	A	Fowler.
	B	Haileeboro.
6131	Oswegatchie River Power Co.	South Edwards.
6132	Oswego River Power Transmission Co.	Syracuse.
50206-1	Oval Wood Dish Co.	Tupper Lake.
6133	Ovid Electric Co.	Taughannock Falls.
6134	Owego Light & Power Co.	Owego.
6135	Panama Power Co.	Panama.
6136	Parishville Electric Light Plant	Parrishville.
6137	Patchogue Electric Light Co.	Patchogue.
6138	Paul Smith's Electric Light & Power & Railroad Co.:	
	A	Franklin Falls.
	B	Keeses Mills.
	C	Saranac Lake.
	D	Union Falls.
6139	Peeksville Lighting & Railroad Co.	Peeksville.
6141	Pennsylvania Tunnel & Terminal Railroad Co.	Long Island City.
6142	Penn Yan & Lake Shore Railway	Park Landing.
6143	Peoples Gas & Electric Co.	Oswego.
6144	Perry Electric Light Co.:	
	A	Perry.
	B	Do.
6145	W. J. Phillips	Manlius.
6146	Phoenix Gas & Electric Co. (Inc.)	Syracuse.
6147	Plattsburg Gas & Electric Co.:	
	A	Indian Rapids.
	B	Plattsburg.
6148	Plattsburg Traction Co.	Do.
6149	Port Henry Light, Heat & Power Co.	Port Henry.
6152	Port Jervis Traction Co.	Port Jervis.
6153	Port Leyden Electric Light & Power Co.	Port Leyden.
6154	Potsdam Electric Light & Power Co.	Potsdam.
6158	Queensborough Gas & Electric Co.	Far Rockaway.
6159	Iroquois Utilities (Inc.)	Randolph.
6160	Red Hook Light & Power Co.	Bingham Mills.
6161	Rensselaer Falls Electric Light & Power Co.	Rensselaer Falls.
6162	Richmond Light & Railroad Co.	Livingston.
6163	Riddell Electric Light & Power Co.	Luzerne.
6164	Alfred Huntington	Ripley.
6165	Riverhead Electric Light Co.	Riverhead.
6166	Rochester Gas & Electric Corporation:	
	B	No. 2a.
	C	No. 26.
	D	No. 4.
	E	New No. 5.
	F	No. 6.
	G	No. 34.
	H	No. 35.
	I	No. 3.
	J	Littleville.
6167	Rochester & Manitou Railroad Co.	Rochester.
6167-1	Rochester & Syracuse Railroad Co. (Inc.)	Syracuse.
6168	Rockland Light & Power Co.:	
	A	Hillburn.
	B	Orangeburg.
6169	Rome Gas, Electric Light & Power Co.	Rome.
6171	Sag Harbor Electric Light & Power Co.	Sag Harbor.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

New York—Continued.

No.	Operating company.	Station.
6173	St. Lawrence River Power Co.	Massena.
6174	St. Lawrence Transmission Co.	Potsdam.
6175	Sulham Manufacturing Co.	St. Regis Falls.
6178	Salem Light, Heat & Power Co.	Salem.
6180	Adirondack Power & Light Corporation	Johnsonville, etc.
6181	Schenectady Railway Co.	Schenectady.
6183	Schodack Light & Power Corporation	Castleton.
6184	Schuyler County Light & Power Co.	Watkins
6185	Scottsville Electrical Light & Gas Co.	Avon.
6188	Seeley Electric Co.	Spencer.
6189	Seneca River Power Co.	Baldwinsville.
50506	Setter Bros. Co.	Cattaraugus.
6190	Sherman Electric Light Co.	Sherman.
6193	Shushan Electric Light Plant	Shushan.
6194	Silver Creek Electric Co.	Silver Creek.
6195	Sinclairville Electric Light Plant	Sinclairville.
6195–1	Snell Power Co.	Higley Falls.
6196	Sodus Gas & Electric Light Co.	Sodus.
6197	Solsville Electric Light & Power Co.	Solsville.
6199	Southern Dutchess Gas & Electric Co.	Beacon.
6199–1	Southern New York Power Co.:	
	A	Walton.
	B	Stilesville.
6200	Southern New York Power & Railway Corporation:	
	A	Colliers.
	B	Hartwick.
6202	Standard Light, Heat & Power Co.	Sidney.
6204	Charles H. Stokes Electric Plant	Kerhonkson.
6205	La Salle Electric Corporation	Niagara Falls.
6207	Suffolk Light, Heat & Power Co.	Southampton.
6209	Syracuse Lighting Co.	Syracuse.
6211	Syracuse & Suburban Railroad Co.	Edward Falls.
6212	Theresa Electric Light Co.	Theresa.
6215	Ticonderoga Electric Light & Power Co.	Ticonderoga.
50712	Ticonderoga Pulp & Paper Co.	Do.
6217	Treadwell Electric Light Plant	Treadwell.
6218	Tri-County Light & Power Co.	Gilboa.
6219	Troy Gas Co.	Troy.
6220	Troy & New England Railway Co.	Albany.
6221	Tuxedo Electric Light Co.	Tuxedo Park.
6222	Twin State Gas & Electric Co.	Hoosick Falls.
6223	Tyler Light & Power Co.	Vernon.
6224	Ulster Electric Light, Heat & Power Co.	Saugerties.
50762	Union Bag & Paper Co.:	
	A	Bakers Falls.
	C	Fenimore.
	F	Moreau.
6225	Union Electric Co.	Whitney Point.
6227	Union Springs Light & Power Co.	Union Springs.
6228	United Electric Light & Power Co.	New York City.
6229	United Gas, Electric Light & Fuel Co.	Hudson Falls.
6230	United Traction Co.:	
	A	Albany.
	B	Troy Falls.
	C	West Sand Lake.
6231	Upper Hudson Electric & Railroad Co.:	
	A	Coxsackie.
	B	Catskill.
	C	Cairo.
	D	Hunter.
6232	Utica Gas & Electric Co.:	
	A	Dolgeville.
	D	Trenton Falls.
	F	Utica.
	G	Little Falls.
6234	Vestal Lighting Co.	Vestal.
6235	Wadhams & Westport Electric Light & Power Co.:	
	A	Wadhams.
	B	Do.
6236	Wallkill Transit Co.	Mechanicstown.
6237	Wallkill Valley Electric Light & Power Co.	Walden.
48985	Warren Curtis Manufacturing Co. (Inc.)	Corinth.
6239	Warrensburgh Electric Light Works	Warrensburgh.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

New York—Continued.

No.	Operating company.	Station.
6240	Warsaw Gas & Electric Co.	Warsaw.
6242	Waterville Gas & Electric Co.	Waterville.
6242–1	Wayland-Steuben Power Co.	Wayland.
6243	Waverly, Sayre & Athens Traction Co.	Waverly.
6244	Wayland Light & Power Co. (Inc.)	Wayland.
6242–1	Wayland-Steuben Power Co.	Do.
6245	Wayne Power Co.	Sodus.
6246	West Branch Light & Power Co.:	
	A.	Stamford.
	B.	Kortright.
6248	Westchester Lighting Co.	New Rochelle.
6250	Western New York Electric Co.	Jamestown.
6251	Western New York Utilities Co.:	
	A.	Medina.
	B.	Waterport.
	C.	Medina.
6252	Western New York & Pennsylvania Traction Co.	Ceres.
6252–1	Western Vermont Power & Light Co.	Carvers Falls.
6254	West Winfield Electric Co.	West Winfield.
50946	Witherbee-Sherman Co.:	
	A.	Port Henry.
	B.	Mineville.
6256	Worcester Electric Light Plant	Worcester.
6257	Wyantskill Hydro-Electric Co.	Wyantskill.
6258	Yates Electric Light & Power Co.	Seneca Mills.
6258–1	Yonkers Electric Light & Power Co.	New York City.
48834	A. C. Cheney Piano Action Co.	Castleton.
48895	Warren Curtis Manufacturing Co. (Inc.)	Corinth.
49143	Endicott, Johnson & Co.	Johnson City.
49275	General Electric Co.	Schenectady.
49320	Gould Paper Co.	Lyons Falls.
50074	Newfane Lumber & Manufacturing Co.	Newfane.
50074–1	New Fabric Cloth Co.	Oswego.
50206	Oval Wood Dish Co.	Tupper Lake.
50256–1	John Dunlop's Sons	Phoenix.
50506	Setter Bros. Co.	Cattaraugus.
50712	Ticonderoga Pulp & Paper Co.	Ticonderoga.
50762	*See* Union Bag & Paper Co.	Bakers Falls, etc.
50946	*See* Witherbee-Sherman Co.	Port Henry, etc.

Pennsylvania.

No.	Operating company.	Station.
7500	Abington Electric Co.	Laplume.
7502	Allegheny Valley Light Co.	Creighton.
7503	Allegheny Valley Street Railway Co.	Pittsburgh.
7504	Allen Street Railway Co.	Bethlehem.
7505	Allentown & Reading Traction Co.	Reading.
7506	Altoona & Logan Valley Electric Railway Co.	Altoona.
7507	Ambler Electric Light, Heat & Motor Co.	Ambler.
7508	Annville & Palmyra Electric Light Co.	Annville.
7509	Anthracite Power Co.	Hazleton.
7510	Ardmore & Llanerch Street Railway Co.	Upper Darby.
7510–1	Arendtsville Roller Mills	Arandtsville.
7510–2	Bangor Electric Co.	Bangor.
7511	Barnesboro Spangler Electric Light Co.	Barnesboro.
7513	Bear Lake Electric Light Plant	Bear Lake.
7514	Beaver County Light Co.	Pittsburgh.
7515	Beaver Springs Electric Light Co.	Beaver Springs.
7516	Beaver Valley Traction Co.	New Brighton.
7517	Bedford Electric Light, Heat & Power Co.	Bedford.
7517–1	Bala & Merion Electric Co.	Philadelphia.
7518	Benton Hydroelectric Co.:	
	A.	Benton.
	B.	Hydroelectric.
7519	Berkshire Electric Co.	Sinking Spring.
7520	Berwich & Nescopeck Street Railway Co.	Berwick.
7522	Bethlehem & Nazareth Passenger Railway Co.	Bethlehem.
7523	Big Spring Electric Co.	Newville.
7524	Birdsboro Electric Co.	Birdsboro.
7526	Blossburg Electric Light & Power Co.	Blossburg.
7527	Blue Mountain Electric Co.	Bethel.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Pennsylvania—Continued.

No.	Operating company.	Station.
7528	Blue Ridge Traction Co.	Danielsville.
7529	Boiling Springs Electric Light Co.	Boiling Springs.
7530	Bolivar Light, Heat & Power Co.	Bolivar.
7531	Boyertown Electric Co.	Boyertown.
7533	Bradford Electric Co.	Bradford.
7534	Brownstown Electric Light, Heat & Power Co.	Brownstown.
7764	Bucks County Electric Co.	Doylestown.
7535	Buffalo & Lake Erie Traction Co.	Erie.
7538	Canton Illuminating Co.	Canton.
7539	Mauch Chunk & Lehighton Transit Co.	Mauch Chunk.
7540	Carlisle Gas & Water Co.:	
	A.	Hydroelectric.
	B.	Steam.
7540-1	Carpenter Electric Co.	Meadville.
7541	Center Electric Co.	Howard.
7542	Centre & Clearfield Railway Co.	Phillipsburg.
7543	Chambersburg, Greencastle & Waynesboro Street Railway Co.	Waynesboro.
7544	Chambersburg & Gettysburg Electric Railway Co.	Chambersburg.
7545	Chambersburg & Shippensburg Railway Co.	Do.
7545-1	Cheltenham Electric Light, Heat & Power Co.	Philadelphia.
7545-2	Chanceford Electric Light & Power Co.	Delta.
7546	Chester County Light & Power Co.	Kennett Square.
7548	Chester Valley Electric Co.	Coatesville.
7549	Chester & Philadelphia Railway.	Philadelphia.
7549-1	Cheswick Power Co.	Colfax.
7550	Christiana & Coatesville Street Railway.	Lancaster.
7551	Citizens Electric Co.	Williamsport.
7552	Citizens Electric Co.	Lewisburg.
7553	Citizens Electric Light & Power Co.	Hughesville.
7555	Citizens Light, Heat & Power Co.	Meyersdale.
7556	Citizens Light & Power Co.	Oil City.
7557	Citizens Traction Co.:	
	A.	Do.
	B.	Franklin.
7558	Clairton Street Railway Co.	Pittsburgh.
7559	Clarion Electric Co.	Clarion.
7560	Cleveland & Erie Railway Co.	Girard.
7561	Clymer Power Co.	Raubsville.
7562	Coalport Light, Heat & Power Co.	Coalport.
7565	Conestoga Traction Co.	Lancaster.
7752	J. W. Conner & Sons.	Orangeville.
57543-1	Consolidation Coal Co.	Jenner.
7562-2	Coopersburg Electric Light, Heat & Power Co.	Coopersburg.
7566	Corry City Electric Light Co.	Corry.
7568	Counties Gas & Electric Co.:	
	B.	Norristown.
	C.	Wayne.
7569	Cresson Electric Light Co.	Cresson.
7570	Cumberland Railway.	Carlisle.
7572	Danville & Sunbury Transit Co.	Danville.
7573	Deal Electric Light & Power Plant.	Cooks Mills.
7574	Delaware County Electric Co.:	
	A.	Beacon.
	B.	Chester.
7575	Delaware County & Philadelphia Electric Railway Co.	Clifton Heights.
7576	Delaware Water Gap Light Plant.	Delaware Water Gap.
7576-1	Delta Electric Light Co.	Delta.
7577	Delta Electric Power Co.	Do.
7578	Delta Water Power Co.	Do.
7579	Dillsburg Light, Heat & Power Co.	Dillsburg.
7581	DuBois Electric & Traction Co.	Du Bois.
7582	Dunbar Electric Co.	Dunbar.
7583	Duquesne Light Co.:	
	A.	Brunots Island.
	B.	Rankin.
	C.	Twentieth Street.
	D.	Thirteenth Street.
	E.	Glenwood.
	F.	Phipps.
	K.	Millvale.
7584	Duquesne & Dravosburg Street Railway Co.	Duquesne.
7585	Eaglesmere Light Co.	Eaglesmere.
7586	East End Passenger Railway Co.	Williamsport.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Pennsylvania—Continued.

No.	Operating company.	Station.
7587	Eastern Pennsylvania Light, Heat & Power Co.:	
	A	Ashland.
	B	Frackville.
	C	Palo Alto.
7588	Eastern Pennsylvania Railway Co	Pottsville.
7589	Easton Transit Co	Allentown.
7590	East Pennsylvania Gas & Electric Co	Bristol.
7591	Ebensburg Light, Heat & Power Co	Ebensburg.
7592	Eckels Light, Heat & Power Co	Conneautville.
7593	Edison Electric Co	Engleside.
7595	Edison Light & Power Co	York.
7882	William Ellsworth Electric Co	Wyalusing.
7596	Ephrata & Lebanon Street Railway Co	Lebanon.
7597	Ephrata & Lebanon Traction Co	Pittsburgh.
7598	Erie County Electric Co.:	
	A	Erie No. 1.
	B	Erie No. 2.
7599	Erie Lighting Co.:	
	A	Front Street.
	B	Peach Street.
7600	Everett Light, Heat & Power Co	Everett.
7601	Excelsior Electric Light, Power & Gas Co	Philadelphia.
7602	Fairchance & Smithfield Traction Co	Uniontown.
7603	Fairmount Park Transportation Co	Belmont.
7605	Frankford, Tacony & Holmesburg Street Railway Co	Philadelphia.
7607	Gallitzin Electric Light Co	Cresson.
7608	Garret Electric Light, Heat & Power Co	Garrett.
7608-1	Harry E. Geiser	Montgomery Mills.
7609	Gettysburg Electric Co	Gettysburg.
7610	Gettysburg Railway Co	Do.
7612	Glen Rock Electric Light & Power Co	Glen Rock.
7615	Greencastle Light, Heat, Fuel & Power Co	Greencastle.
7616	Halfpenny & Grove	Mifflinburg.
7617	Hamburg Gas & Electric Co	Hamburg.
7617-1	Hanover Light, Heat & Power Co	Hanover.
7618	Hanover & McSherrytown Street Railway Co	Do.
7618-1	Harmony Electric Co	Harmony.
7619	Harrisburg Light & Power Co.:	
	A	Cedar Street.
	B	Ninth Street.
7620	Harrisburg Railways Co	Harrisburg.
7622	Hastings Electrical Co	Hastings.
7623	Hershey Transit Co	Hershey.
7624	Highland Grove Traction Co	McKeesport.
7624-1	Hinkletown-Conestoga Valley Electric Co	Hinkletown.
7625	Home Electric Co	Coudersport.
7627	Home Electric Light & Steam Heating Co	Tyrone.
7628	Homestead & Mifflin Street Railway Co	Homestead.
7629	Honesdale Consolidated Light, Heat & Power Co	Honesdale.
7630	Houtzdale Electric Light, Heat & Power Co	Houtzdale.
7631	Hummelstown Water & Power Co	Harrisburg.
7632	Huntingdon, Lewistown & Juniata Valley Traction Co	Huntingdon.
7633	Hyndman Electric Light, Heat & Power Co	Hyndman.
7634	Indiana County Street Railway Co	Indiana.
7636	Intercourse Electric Light, Heat & Power Co	Intercourse.
7637	Irwin-Herminie Traction Co	Irwin.
7639	Jefferson Electric Co.:	
	A	Punxsutawney.
	B	Reynoldsville.
7640	Jersey Shore Traction Co.:	
	A	Florence.
	B	Rathmel Junction.
7640-1	Jersey Shore Electric Co	Jersey Shore.
7641	Jersey Shore Electric Street Railway Co	Do.
7642	Jersey Shore & Antes Fort Railroad Co	Do.
7643	Johnsonburg Light & Power Co	Johnsonburg.
7644	Johnstown Traction Co	Johnstown.
2800	Keystone Electric Service Corporation:	
	A	Ridgway.
	B	Kane.
7647	Kittanning & Leechburg Railways Co	Pittsburgh.
7647-1	Lackawanna Light Co	Scranton.
7648	Lackawanna & Wyoming Valley Power Co	Do.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Pennsylvania—Continued.

No.	Operating company.	Station.
7649	Lancaster County Railway & Light Co.	Lancaster.
7650	Lancaster Electric Light, Heat & Power Co.:	
	A	Rock Hill.
	B	Slackwater.
7652	Lancaster & York Furnace Street Railway Co.	Philadelphia.
7653	Langhorne Electric Light & Power Co.	Langhorne.
7658	Lehighton Electric Light & Power Co.	Lehighton.
7659	Lehigh Traction Co.	Hazelton.
7661	Lehigh Valley Transit Co.	Allentown.
7662	Lewisburg, Milton & Watersontown Passenger Railway Co.	Milton.
7663	Lewistown & Reedsville Electric Railway Co.	Lewistown.
7664	Lilly Electric Light, Heat & Power Plant.	Lilly.
7665	Lock Haven Electric Light & Power Co.	Lock Haven.
7667	Luzerne County Gas & Electric Co.	Plymouth.
7668	Lycoming Edison Co.	Williamsport.
7669	Lykens Valley Light & Power Co.:	
	A	Wiconisco.
	B	Williamstown.
7670	Macungie Electric Light, Heat & Power Co.	Macungie.
7672	Mansfield Electric Co.	Mansfield.
7539	Mauch Chunk & Lehighton Transit Co.	Mauch Chunk.
7674	Mauch Chunk Heat, Power & Electric Light Co.	Do.
7675	Media, Glen Ridle & Rockdale Electric Street Railway Co.	Media.
7676	Mercer County Light, Heat & Power Co.	Greenville.
7677	Mercersburg, Lehmasters & Markes Electric Co.	Markes.
7678	Metropolitan Edison Co.:	
	A	Lebanon.
	B	Klapperthal.
	C	West Reading.
7679	Meyersdale Electric Light, Heat & Power Co.	Meyersdale.
7680	Middleburg Light, Heat & Power Co.	Clearfield.
7681	Midland Electric Light & Power Co.	Pittsburgh.
7682	Juniata Public Service Co.	Millersburg.
7683	Montgomery Transit Co.	Norristown.
7684	Montgomery & Muncy Electric Light, Heat & Power Co.	Montgomery.
7685	Montoursville Electric Light Co.	Montoursville.
7686	Montoursville Passenger Railway Co.	Do.
7688	Mount Holly Light, Heat & Power Co.	Mount Holly Springs.
7688–1	Mount Jewett Electric Light Co.	Mount Jewett.
7689	Mount Penn Gravity Railroad Co.	Reading.
7690	Municipal electric plant.	Allegheny.
7691	do.	Aspinwall.
7691–1	do.	Bally.
7691–2	do.	Bechtelsville.
7692	do.	Berlin.
7693	do.	Catawissa.
7694	do.	Chambersburg.
7695	do.	Conemaugh.
7696	do.	Confluence.
7697	do.	Coraopolis.
7698	do.	Danville.
7699	do.	Duncannon.
7700	do.	Easton.
7701	do.	Ellwood City.
7702	do.	Emporium.
7703	do.	Ephrata.
7704	do.	Etna.
7705	do.	Ford City.
7707	do.	Goldsboro.
7708	do.	Grove City.
7708–1	do.	Hatfield.
7709	do.	Kutztown.
7710	do.	Lansdale.
7711	do.	Meadville.
7712	do.	Media.
7713	do.	Middletown.
7714	do.	Mifflinburg.
7716	do.	New Freedom.
7717	do.	New Wilmington.
7718	do.	Norristown.
7719	do.	Olyphant.

Table 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Pennsylvania—Continued.

No.	Operating company.	Station.
7720	Municipal electric plant	Peckville.
7721	.....do	Pennsburg.
7722	.....do	Perkasie.
7723	.....do	Pitcairn.
7724	.....do	Quakertown.
7724-1	.....do	Royalton.
7725	.....do	St. Clair.
7726	.....do	Schuylkill Haven.
7727	.....do	Sharpsburg.
7728	.....do	Souderton.
7729	.....do	Tarentum.
7730	.....do	Titusville.
7730-1	.....do	Wampum.
7731	.....do	Weatherly.
7731-1	.....do	Womelsdorf.
7732	Neversink Mountain Railway Co	Reading.
7733	Newcastle Electric Co	Newcastle.
7734	Newcastle & Lowell Railway Co	Youngstown.
7735	New Holland, Blue Ball & Terre Hill Street Railway Co	Lancaster.
7736	New Hope Electric Co	New Hope.
7737	New Kingstown Electric Light, Heat & Power Co	New Kingstown.
7738	Newmanstown Electric Light & Power Co	Lebanon.
7740	Nicholson Light, Heat & Power Co	Nicholson.
7741	Norristown Transit Co	Philadelphia.
7743	Northampton Traction Co	Easton.
7748	Northwestern Electric Service Co	Erie.
7749	Northwestern Pennsylvania Railway Co	Meadville.
7750	Oakdale & McDonald Street Railway Co	Pittsburgh.
7751	Oley Valley Railway Co	Reading.
7752	J. W. Conner & Sons	Orangeville.
7753	Oxford Electric Co	Oxford.
7754	Panther Valley Electric Co	Lansford.
7755	Patterson Heights Street Railway Co	Beaver Falls.
7756	Paupack Electric Co	Hawley.
7757	Penn Central Light & Power Co.:	
	C	Eighteenth Street, Altoona.
	D	Twentieth Street, Altoona.
7758	Penn Central Power & Transmission Co	Williamsburg.
7760	Penn Hydro-Electric Co	Warrior Ridge.
7761	Penn Public Service Corporation:	
	A	Blairsville.
	B	Clearfield.
	C	Philipsburg B.
	E	Indiana.
	F	Philipsburg A.
	G	Broad Street.
	H	Vine Street.
	J	Somerset.
	K	Rockwood.
7763	Pennsylvania Light & Power Co	Pittsburgh.
7764	Bucks County Electric Co	Doylestown.
7764-1	Pennsylvania-New Jersey Railway Co	Yardley.
7765	Pennsylvania Power Co	Ellwood City.
7765-1	Pennsylvania Power & Light Co.:	
	A	Harwood Mines.
	B	Hauto.
	C	Irondale.
	D	Milton.
	E	Mount Carmel.
	F	Selinsgrove.
	G	Shamokin.
	H	Sunbury.
7766	Pennsylvania Railroad	Philadelphia.
7767	Pennsylvania Utilities Co.:	
	B	Dock Street.
	D	South Side No. 1.
	F	East Stroudsburg.
7768	Pennsylvania Water & Power Co	Holtwood.
7769	Pennsylvania & Maryland Street Railway Co	Boynton.
7771	Peoples Street Railway Co. of Nanticoke & Newport	Wanamie.
7773	Philadelphia Electric Co.:	
	A	Schuylkill No. 1.
	B	Carpenter.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Pennsylvania—Continued.

No.	Operating company.	Station.
7773	Philadelphia Electric Co.—Continued.	
	C	Edison.
	D	Callowhill.
	G	Tacony.
	H	Delaware.
	K	Schuylkill.
7774	Philadelphia Hydro-Electric Co	Manayunk.
7775	Philadelphia Railways Co	Philadelphia.
7776	Philadelphia Rapid Transit Co.:	
	A	Beach Street.
	B	Market Street.
	C	Wyoming Avenue.
	D	Upper Darby.
	E	Mount Vernon Street.
7777	Philadelphia Suburban Gas & Electric Co.:	
	C	West Chester.
	D	Cromby.
7778	Philadelphia & Easton Electric Railway Co	Doylestown.
7779	Philadelphia & Garrettford Street Railway Co	Upper Darby.
7780	Philadelphia & West Chester Traction Co.:	
	A	Ridley Creek.
	B	Llanerch.
7781	Philadelphia & Western Railway Co	Upper Darby.
7782	Phoenixville, Valley Forge & Strafford Electric Railway Co	Phoenixville.
7783	Phoenix Water Power Co	Do.
7785	Pine Grove Electric Light, Heat & Power Co	Pine Grove.
7786	Pittsburgh, Harmony, Butler & Newcastle Railway Co	Harmony.
7788	Pittsburgh Railways Co	Pittsburgh.
7789	Pittsburgh & Allegheny Valley Traction Co	Do.
7790	Pittsburgh & Beaver Street Railway Co	Do.
7791	Pittsburgh, Mars & Butler Railway	Renfrew.
7792	Plymouth & Larksville Railway Co	Wilkes-Barre.
7793	Pottstown & Phoenixville Railway Co	Philadelphia.
7793-1	Prospect Rock Light & Power Co	Georgetown.
7794	Railroad Electric Light & Power Co	Railroad.
7795	Raystown Water Power Co.:	
	A	Main.
	B	Auxiliary.
7796	Reading Transit & Light Co	Reading.
7797	Redbank Electric Co	New Bethlehem.
7798	Renovo Edison Light, Heat & Power Co	Renovo.
7800	*See* Keystone Electric Service Corporation	Ridgway, etc.
7801	Ringtown Electric Light, Heat & Power Co	Ringtown.
7802	Roaring Spring Light, Heat & Power Co	Roaring Spring.
7803	Rockwood Electric Co	Rockwood.
7804	St. Marys Electric Light Co	St. Marys.
7805	Sayre Electric Co	Sayre.
7805-1	Schuylkill Electric Co	Girardville.
7806	Schuylkill Gas & Electric Co	Allentown.
7807	Schuylkill Light, Heat & Power Co	Girardville.
7808	Schuylkill Railway Co	Do.
7809	Schuylkill Valley Traction Co	Collegeville.
7811	Scranton Electric Co.:	
	A	Pittston.
	B	Suburban.
	C	Linden Street.
7812	Scranton Railway Co	Scranton.
7813	Scranton & Binghamton Railroad Co	Dalton.
7814	Shamokin & Edgewood Electric Railway Co	Shamokin.
7815	Shamokin & Mount Carmel Transit Co	Mount Carmel.
7816	Sharon & New Castle Street Railway Co	Youngstown.
7817	Shenango Valley Electric Light Co	Sharon.
7818	Shermans Valley Light, Heat & Power Co	Landisburg.
7819	Shippenburg Gas & Electric Co.:	
	A	Roxbury.
	B	Shippensburg.
	C	Lurgan.
7820	Slate Belt Electric Street Railway Co	Penn Argyl.
7820-1	Solar Electric Co	Brookville.
7821	South Bethlehem & Saucon Street Railway Co	South Bethlehem.
7822	Southern Cambria Railway Co	Brookdale.
7823	Southern Pennsylvania Traction Co	Chester.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Pennsylvania—Continued.

No.	Operating company.	Station.
7825	South Side Passenger Railway Co.	Williamsport.
7827	State Center Electric Co.	Milesburg.
7828	Strasburg Electric Light, Heat & Power Co.	Strasburg.
7829	Stroudsburg Electric Light & Power Co.	Allentown.
7830	Stroudsburg Traction Co.	Stroudsburg.
7832	Sunbury & Susquehanna Railway	Rolling Green.
7833	Susquehanna County Light & Power Co.:	
	A	Oakland.
	B	Lanesboro.
7833-1	Susquehanna Traction Co.	Lock Haven
7834	Tarentum, Brackenridge & Butler Street Railway Co.	Tarentum.
7834-1	Tatamy Light, Heat & Power Co.	Tatamy.
7835	Titusville Light & Power Co.	Titusville.
7836	Titusville Traction Co.	Do.
7837	Titusville & Cambridge Railroad Co.	Do.
7838	Towanda Electric Illuminating Co.	Towanda.
7839	Trenton, Bristol & Philadelphia Street Railway Co.	Croydon.
7840	Treverton Electric Light & Power Co.	Treverton.
7841	Tri-County Electric Co.	Lincoln.
7842	Troy Electric Light, Heat & Power Co.	Troy.
7843	Tunkhannock Electric Co.	Tunkhannock
7845	Union City Electric Light Co.	Union City.
7846	United Electric Co.	Lemoyne.
7848	United Electric Light Co.	Wilmerding.
7849	United Light, Heat & Power Co.	Stoyestown.
7851	United Lighting Co.	Albion.
7852	Vallamont Traction Co.	Williamsport.
7853	Vandergrift Electric Light & Power Co.	Vandergrift.
7854	Warren Light & Power Co.	Warren.
7855	Warren Street Railway Co.	Stoneham.
7856	Warren & Jamestown Street Railway Co.	Warren.
7857	Waterford Electric Light Co.	Waterford.
7858	Waynesburg & Blackville Street Railway Co.	Waynesburg.
7858-1	Waynesboro Electric Co.	Waynesboro.
7859	Webster, Monessen, Belle Vernon & Fayette City Street Railway Co.	Charleroi.
7860	Weimer Electric Light & Power Co.	Mount Gretna.
7861	Wellsboro Electric Co.	Wellsboro.
7862	West Chester, Kennett & Wilmington Electric Railway Co.	Kennett Square.
7863	Westmoreland County Railway Co.	Pittsburgh.
7866	West Penn Power Co.:	
	A	Ohiopyle.
	B	Connellsville.
	C	Ligonier.
	E	Washington.
	F	Waynesburg.
	G	Kittanning.
	H	Butler.
	J	Springdale.
7867	West Penn Railways Co.	Pittsburgh.
7868	West Side Electric Street Railway Co.	Charleroi.
7870	Whitehall Street Railway Co.	Allentown.
7871	White Haven Electric Illuminating Plant	White Haven.
7872	White Oak Light, Heat & Power Co.	Hollsopple.
7873	Wilkes-Barre Co.:	
	A	North River Street
	B	Bennett Street
7874	Wilkes-Barre Railway Co.	Wilkes-Barre.
7876	Wilkes-Barre & Hazleton Railway Co.	St. Johns.
7877	Wilkes-Barre & Wyoming Valley Traction Co.	Wilkes-Barre.
7878	Williamsport Passenger Railway Co.	Williamsport.
7879	Windber Electric Co.	Windber.
7880	Woodlawn & Southern Street Railway	Pittsburgh.
7881	Wrightsville Light & Power Co.	Wrightsville.
7882	William Ellsworth Electric Co.	Wyalusing.
7882-1	Yeagertown Water Power Co.	Yeagertown.
7883	Yorkhaven Water & Power Co.	Yorkhaven.
7884	York Railways Co.	York.
7885	Zelienople Light & Power Co.	Zelienople.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Rhode Island.

No.	Operating company.	Station.
7900	*See* Eastern Massachusetts Street Railway Co	Portsmouth, etc.
7901	Blackstone Valley Gas & Electric Co.:	
	B	Pawtucket.
	C	Woonsocket.
	D	Jencks Lane.
7902	Bristol County Gas & Electric Co	Bristol.
7900	Eastern Massachusetts Street Railway Co.:	
	A	Portsmouth.
	B	Newport.
7904	Municipal electric plant	Pascoag.
7905	Narragansett Electric Lighting Co	Providence.
7906	Narragansett Pier Electric Light & Power Co	Wakefield.
7909	Providence, Warren & Bristol Railroad Co	Warren.
7910	Rhode Island Co	Providence.
7911	Rhode Island Power Transmission Co	Worcester.
7911-1	F. A. Sayles	Samoset.
7913	Tiverton Electric Light Co	Tiverton.
7915	Westerly Light & Power Co	Westerly.
7914	West Gloucester Light & Power Co	Putnam
7916	Wickford Light & Water Co	Wickford.

Vermont.

8700	William F. Allen Light Co	Canaan.
8701-1	Bellows Falls Electric Co.:	
	A	Rockingham.
	B	Water.
8703	W. E. Benson	Weston.
8703-1	Berkshire Street Railway Co	New Haven.
8705	Bradford Electric Lighting Co	Bradford.
8706	Bridgewater Electric Co	Bridgewater.
8708	Burlington Light & Power Co.:	
	A	Colchester.
	B	Essex Junction.
8708-1	Burlington Traction Co	Vergennes.
8709	Chester Water & Light Co	Chester.
8712	*See* Vermont Hydro-Electric Corporation	Cavendish, etc.
8713	Connecticut River Power Co	Vernon.
8715	Eastern Vermont Public Utilities Corporation:	
	A	Barnet.
	B	Groton.
	C	Do.
	D	Ryegate.
	E	Wells River.
	F	Joes Pond.
8716	Electric Light & Power Co	South Londonderry.
8718	Fall Mountain Electric Co	Forest.
8719	Frontier Electric Co	North Troy.
8720	Glover Electric Light Plant	Glover.
8721	Hortonia Power Co.:	
	A	Bethel.
	B	Bristol.
	C	Gaysville.
	D	Bethel.
	F	Hortonville.
	G	Brandon.
	H	Salisbury.
	J	Silver Lake.
	L	Middlebury.
	M	Waybridge.
8723	Island Pond Electric Co	West Charleston.
8724	Jones & Lamson Power Co	Perkinsville.
8726	B. J. Kendall Co	Enosburg Falls.
8727	Lunenburg Manufacturing Co	Lunenburg.
8728	Lyman Falls Power Co	Bloomfield.
8731	Middlebury Electric Co	Middlebury.
8733	Missisquoi Lighting Co	Highgate.
8734	Missisquoi Pulp Co	Sheldon.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Vermont—Continued.

No.	Operating company.	Station.
8735	Montpelier & Barre Light & Power Co.:	
	A	Berlin.
	B	Middlesex.
	C	Moretown.
	D	Montpelier.
	E	Moretown.
	F	North Duxbury.
	G	Montpelier.
8736	Mount Mansfield Electric Railroad Co	Stowe.
8737	Municipal electric plant	West Charleston.
8738	.....do	Burlington.
8740	.....do	Enosburg Falls.
8741	.....do	Wolcott.
8742	.....do	Hyde Park.
8743	.....do	Johnson.
8744	.....do	Ludlow.
8745	.....do	Lyndonville.
8746	.....do	Cadys Falls.
8747	.....do	Northfield.
8748	.....do	Orleans.
8749	.....do	Readsboro.
8750	.....do	Highgate.
8751	.....do	West Burke.
8752	Nelson & Hall Co.:	
	A	Samsonville.
	B	Montgomery Center.
8752–1	New England Power Co	Readsboro.
8753	Newport Electric Light Co	Newport.
8754	Pittsford Power Co	Pittsford.
8755	Powers Electric Co	Richmond.
8756	Public Electric Light Co.:	
	A	St. Albans.
	B	Fairfax Falls.
8758	Reading Light & Power Co	Felchville.
8762	Rochester Electric Light & Power Co	Rochester.
8763	Royalton Power Co	Royalton.
8764	Rutland Railway Light & Power Co	Rutland.
8765	St. Albans & Swanton Traction Co	St. Albans.
8765–1	Sheldon Light & Power Co	Sheldon Springs.
8766	W. J. Smith	Sheffield.
8767	Springfield Electric Railway Co	Springfield.
8768	Stamford Light, Heat & Power Co	North Adams, Mass.
8769	Sweat-Comings Co	Richford.
9771	Twin State Gas & Electric Co.:	
	A	Bennington.
	B	St. Johnsbury No. 1.
	C	St. Johnsbury No. 2.
	D	St. Johnsbury No. 3.
	E	St. Johnsbury No. 4.
	F	West Dummerston.
	G	St. Johnsbury No. 5.
8712	Vermont Hydro-Electric Corporation:	
	A	Cavendish.
	B	Mendon.
8774	Vermont Marble Co.:	
	A	Beldens.
	B	Center Rutland.
	C	Florence.
	D	Huntington Falls.
	E	Proctor.
	F	West Rutland.
8774–1	Vermont & Quebec Power Corporation	Stevens Mill.
8775	Vermont Soapstone Co	Perkinsville.
8777	Wilmington Electric Light Co	Wilmington.
8778	Windsor Electric Light Co.:	
	A	Windsor No. 1.
	B	Windsor No. 2.
8780	Woodbury Granite Co.:	
	A	Mackville.
	B	Do.
8781	Woodstock Electric Co	Taftsville.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Virginia.

No.	Operating company.	Station.
8800	Abingdon Utilities Co	Abingdon.
8801	Alexandria County Lighting Co	Alexandria.
8802	Altavista Light & Power Corporation	Altavista.
8803	Appalachian Power Co.:	
	A	No. 2, Byllesby.
	B	No. 4, Byllesby.
	C	Glen Lyn.
	D	Clinchfield.
8804	Arlington Electric Co	Alexandria.
8806	Bloxom Electric Light Co	Bloxom.
8807	Shenandoah Traction Co	Staunton.
8808	Braddock Light & Power Co	Roslyn.
8809	Charlottesville & Albemarle	Charlottesville.
8810	Chatham Light & Power Co	Chatham.
8812	Nottoway Light & Power Co	Crewe.
8813	Culpeper Light & Ice Co	Culpeper.
8814	Damascus Light & Power Co	Damascus.
8815	Danville Traction & Power Co	Danville.
8816	Delmarvia Light, Heat & Refining Corporation	Chincoteague Island.
8817	Electric Light & Power Co	Remington.
8818	Electric Transmission Company of Virginia:	
	A	Big Stone Gap.
	B	Pocket.
8819	Emporia Hydro-Electric Power Corporation	Emporia.
8820	Exmore Light & Power Co	Exmore.
8822	Grundy Light & Power Co	Grundy.
8825	J. H. & C. T. Hopkins	Parksley.
8826	Halifax Hydro-Electric Co	Houston.
8827	Independence Electric & Milling Co	Independence.
8828	Leesburg Electric Co.:	
	A	Steam.
	B	Goose Creek.
8829	Light & Power Co. of Rockymount	Rockymount.
8830	London Light & Power Co	Purcellville.
8831	Lynchburg Traction & Light Co.:	
	A	Reusen.
	B	Blackwater.
8832	J. D. Manor & Co	New Market.
8833	Monterey Garage & Light Co	Monterey.
8834	Municipal electric plant	Basic.
8835	do	Bedford.
8837	do	Chase City.
8838	do	Danville.
8838–1	do	Dayton.
8839	do	Farmville.
8840	do	Franklin.
8842	do	Riverton.
8843	do	Gordonsville.
8844	do	Harrisonburg.
8845	do	Lawrenceville.
8846	do	Manassas.
8847	do	Martinsville.
8848	do	Richmond.
8849	do	Salem.
8850	do	Shenandoah.
8851	do	Staunton.
8852	Giles Power Co	Narrows.
8853	New York, Philadelphia & Norfolk Railroad	Cape Charles.
8854	Newport News & Hampton Railway, Gas & Electric Co	Hampton.
8857	Norfolk Southern Railroad Co	Bayville.
8858	North River Electric Co	Bridgewater.
8812	Nottoway Light & Power Co	Crewe.
8860	Old Dominion Power Co	Dorchester.
8861	Onancock Light & Power Co	Onancock.
8862	Orange Light Co	Orange.
8863	Peninsula Light & Power Co	Tasley.
8865	Peoples Light, Heat & Power Corporation	West Point.
8866	Petersburg, Hopewell & City Point Railway Co	Petersburg.
8867	Prince George Electric Light & Power Co	Hopewell.
8868	Radford Water Power Co	Radford.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Virginia—Continued.

No.	Operating company.	Station.
8869	Rappahannock Electric Light & Power Co.:	
	A	Steam, Fredericksburg.
	B	Hydroelectric, Fredericksburg.
8871	Municipal electric plant	Richland.
8871-1	Richmond-Ashland Railway Co	Richmond.
8872	Richmond & Chesapeake Bay Railway Co	Do.
8876	Riverside Light & Power Co	Waynesboro.
8877	Roanoke Railway & Electric Co.:	
	A	Niagara.
	B	Roanoke.
8880	Rural Retreat Power Co	Rural Retreat.
8881	Shenandoah River Light & Power Corporation	Luray.
8807	Shenandoah Traction Co	Staunton.
8882	Smithfield Light & Power Co	Smithfield.
8883	South Boston Power Co	South Boston.
8884	South Hill Manufacturing Co	South Hill.
8885	Spottsylvania Power Co	Fredericksburg.
8886	Stanley Milling Co	Stanley.
8887	Staunton Lighting Co	Staunton.
8889	Tazewell Electric Light & Power Co	Tazewell.
8890	Tazewell Street Railway Co	Do.
8890-1	Victoria Ice, Light & Power Co	Victoria.
8891	Valley Light & Power Co	Woodstock.
8892	Virginia Alberene Corporation:	
	A	No. 1, Schuyler.
	B	No. 2, Schuyler.
	C	No. 3, Schuyler.
8898	Warrenton Electric Light & Power Co	Warrenton.
8899	Washington & Old Dominion Railroad Co	Rosslyn.
8899-1	Weyers Cave Light & Power Co.:	
	A	Rockland.
	B	Grottoes.
8899-2	Woodstock Electric Light & Power Co	Woodstock.
8899-3	Waverly Light & Power Co	Waverly.

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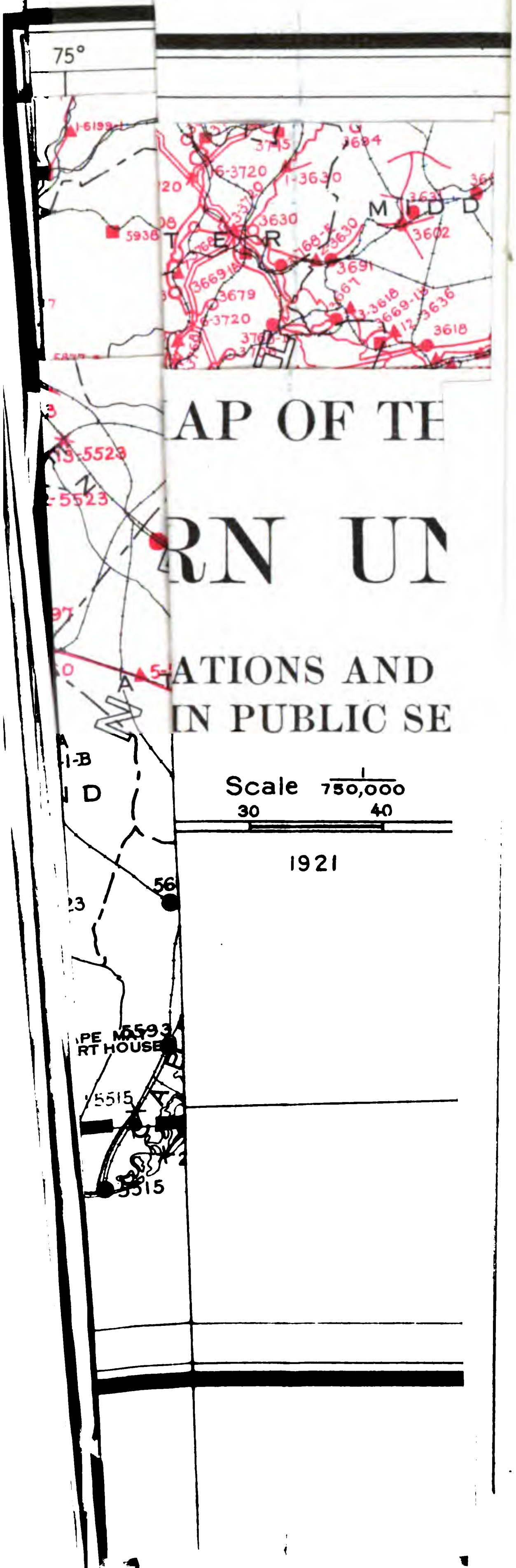

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